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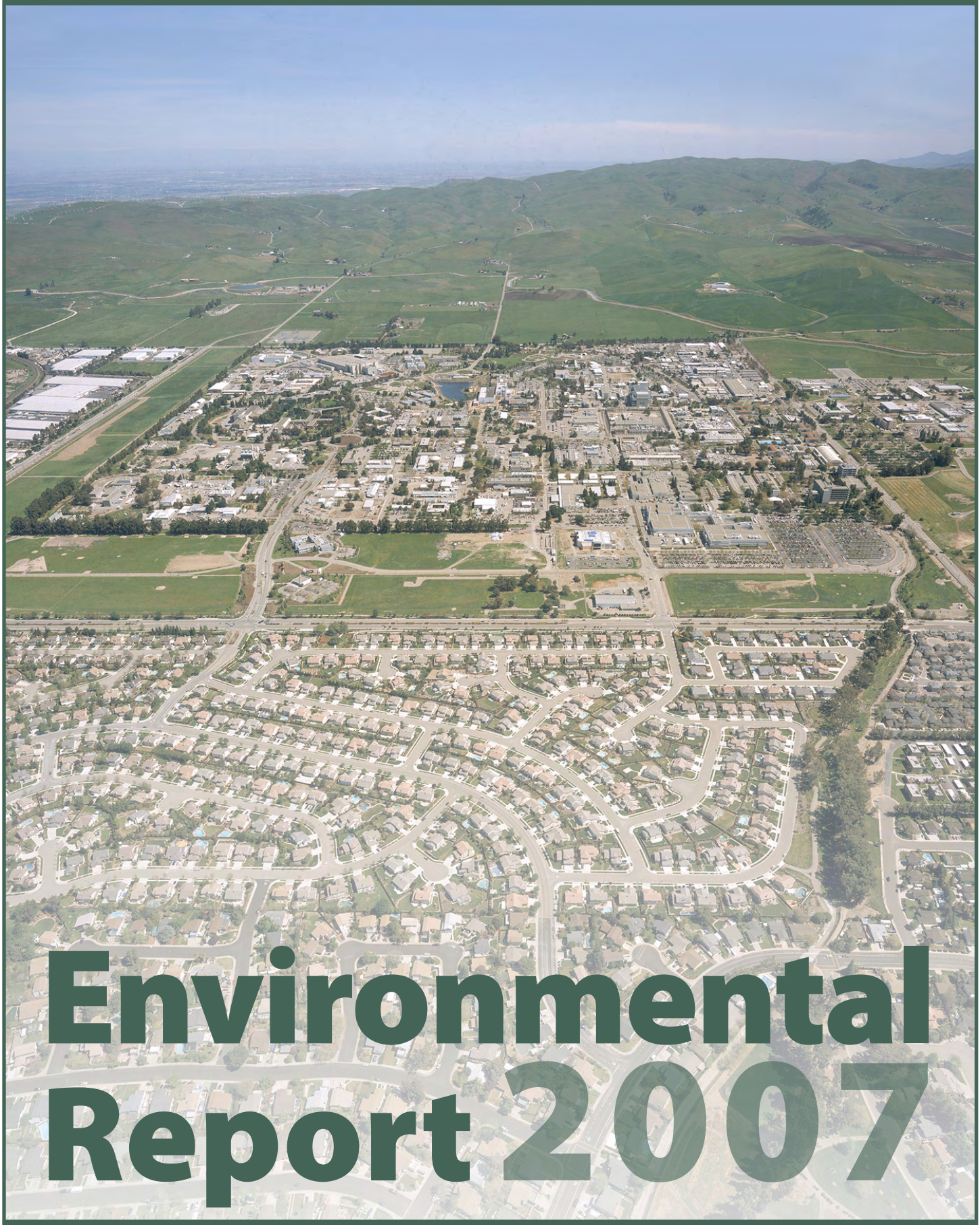

Environmental Report 2007

Lawrence Livermore National Laboratory

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This report can be accessed on the Internet at https://saer.llnl.gov/.

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Lawrence Livermore National Laboratory

Environmental Report 2007

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DOE letter

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To: Distribution

Subject: 2007 Annual Site Environmental Report for the Lawrence Livermore National Laboratory

The Annual Site Environmental Report was prepared by the Lawrence Livermore National Laboratory (LLNL) for the Department of Energy/National Nuclear Security Administration (NNSA)/Livermore Site Office. It provides a comprehensive summary of the environmental program activities at LLNL for calendar year 2007. This report is prepared annually and is made available to relevant regulatory agencies and other interested organizations and individuals.

The information in this report has been reviewed by NNSA and LLNL personnel for accuracy. The review was based on quality assurance and quality control protocols applied to monitoring and data analyses at LLNL.

LLNL is committed to achieving continuous improvement in environmental performance through pollution prevention, energy efficiency, and other measures. Environmental monitoring of emission sources indicates compliance with environmental regulations. Remediation activities continue to reduce contaminants at both the Livermore Site and Site 300.

The environmental protection and compliance programs at LLNL are implemented to ensure the health and safety of employees, and residents of neighboring communities, in addition to the preservation of the environment.

Sincerely,

Michael G. Brown
Assistant Manager for
Environmental Stewardship

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Preface

The purposes of the *Lawrence Livermore National Laboratory Environmental Report 2007* are to record Lawrence Livermore National Laboratory's (LLNL's) compliance with environmental standards and requirements, describe LLNL's environmental protection and remediation programs, and present the results of environmental monitoring at the two LLNL sites—the Livermore site and Site 300. The report is prepared for the U.S. Department of Energy (DOE) by LLNL's Environmental Protection Department. Submittal of the report satisfies requirements under DOE Order 231.1A, Environmental Safety and Health Reporting, and DOE Order 5400.5, Radiation Protection of the Public and Environment.

The report is distributed electronically and is available at https://saer.lln.gov/, the website for the LLNL annual environmental report. Previous LLNL annual environmental reports beginning in 1994 are also on the website. Some references in the electronic report text are underlined, which indicates that they are clickable links. Clicking on one of these links will open the related document, data workbook, or website that it refers to.

The report begins with an executive summary, which provides the purpose of the report and an overview of LLNL's compliance and monitoring results. The first three chapters provide background information: Chapter 1 is an overview of the location, meteorology, and hydrogeology of the two LLNL sites; Chapter 2 is a summary of LLNL's compliance with environmental regulations; and Chapter 3 is a description of LLNL's environmental programs with an emphasis on the Environmental Management System including pollution prevention.

The majority of the report covers LLNL's environmental monitoring programs and monitoring data for 2007: effluent and ambient air (Chapter 4); waters, including wastewater, storm water runoff, surface water, rain, and groundwater (Chapter 5); and terrestrial, including soil, sediment, vegetation, foodstuff, ambient radiation, and special status wildlife and plants (Chapter 6). Complete monitoring data, which are summarized in the body of the report, are provided in Appendix A.

The remaining three chapters discuss the radiological impact on the public from LLNL operations (Chapter 7), LLNL's groundwater remediation program (Chapter 8), and quality assurance for the environmental monitoring programs (Chapter 9).

The report uses Système International units, consistent with the federal Metric Conversion Act of 1975 and Executive Order 12770, Metric Usage in Federal Government Programs (1991). For ease of comparison to environmental reports issued prior to 1991, dose values and many radiological measurements are given in both metric and U.S. customary units. A conversion table is provided in the glossary.

The report is the responsibility of LLNL's Environmental Protection Department. Monitoring data were obtained through the combined efforts of the Environmental Protection Department;

Environmental Restoration Department; Chemistry, Materials and Life Sciences Environmental Services' Environmental Monitoring Radiation Laboratory; and the Hazards Control Department.

Special recognition is given to the technologists who gathered the data—Gary A. Bear, Karl Brunckhorst, David J. Castro, Crystal Foster, Steven Hall, Renee Needens, Terrance W. Poole, Donald G. Ramsey, and Robert Williams; and to the data management personnel—Hildy Kiefer, Kimberley A. Swanson, Suzanne Chamberlain, Nancy Blankenship, Connie Wells, Lisa Graves, Courtney Cook, Della Burruss, and Susan Lambaren. Special thanks to Loni Hoellworth for helping with distribution.

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Executive Summary

Lawrence Livermore National Laboratory (LLNL) is a premier research laboratory that is part of the National Nuclear Security Administration (NNSA) within the U.S. Department of Energy (DOE). As a national security laboratory, LLNL is responsible for ensuring that the nation's nuclear weapons remain safe, secure, and reliable. The Laboratory also meets other pressing national security needs, including countering the proliferation of weapons of mass destruction and strengthening homeland security, and conducts major research in atmospheric, earth, and energy sciences; bioscience and biotechnology; and engineering, basic science, and advanced technology. The Laboratory serves as a scientific resource to the U.S. government and a partner to industry and academia.

Since its inception in 1952 until October 1, 2007, LLNL was managed by the University of California. In May 2007, DOE selected Lawrence Livermore National Security, LLC (LLNS), to manage the Laboratory under a seven-year contract that began on October 1, 2007.

LLNL operations release a variety of constituents into the environment via atmospheric, surface water, and groundwater pathways. Some of the constituents, such as particles from diesel engines, are common at many types of facilities while others, such as radionuclides, are unique to facilities like LLNL. All releases are highly regulated and carefully monitored.

Safe, secure, and efficient operations that provide a safe, clean environment for employees and neighboring communities are a necessary part of the Laboratory's research and development programs and underpin their success. Experts in environment, safety and health (ES&H) support all Laboratory activities. LLNL's radiological control program ensures that radiological exposures and releases are reduced to as low as reasonably achievable to protect the health and safety of its employees, contractors, the public, and the environment.

LLNL is committed to enhancing its environmental stewardship and reducing any impacts its operations may have on the environment. The Laboratory encourages the public to participate in matters related to the Laboratory's environmental impact on the community by soliciting citizens' input on matters of significant public interest and through various communications. The Laboratory also provides public access to information on its ES&H activities.

LLNL consists of two sites—an urban site in Livermore, California, referred to as the "Livermore site," which occupies 1.3 square miles; and a rural Experimental Test Site, referred to as "Site 300," near Tracy, California, which occupies 10.9 square miles. In 2007 the Laboratory had a staff of more than 8000.

Purpose and Scope of the Environmental Report

The purposes of the *Environmental Report 2007* are to record LLNL's compliance with environmental standards and requirements, describe LLNL's environmental protection and remediation programs, and present the results of environmental monitoring. Specifically, the

report discusses LLNL's Environmental Management System; describes significant accomplishments in pollution prevention; presents the results of air, water, vegetation, and foodstuff monitoring; reports radiological doses from LLNL operations; summarizes LLNL's activities involving special status wildlife, plants, and habitats; and describes the progress LLNL has made in remediating groundwater contamination.

Environmental monitoring at LLNL, including analysis of samples and data, is conducted according to LLNL's Environmental Protection Department Quality Assurance Management Plan, which is based on DOE Order 414.1C, Quality Assurance.

This report is prepared for DOE by LLNL's Environmental Protection Department. Submittal of the report satisfies requirements under DOE Order 231.1A, Environmental Safety and Health Reporting, and DOE Order 5400.5, Radiation Protection of the Public and Environment. The report is distributed in electronic form and is available to the public at https://saer.llnl.gov/, the website for the LLNL annual environmental report. Previous LLNL annual environmental reports beginning in 1994 are also on the website.

Regulatory Permitting and Compliance

LLNL undertakes substantial activities to comply with many federal, state, and local environmental laws. The major permitting and regulatory activities that LLNL conducts are required by the Clean Air Act; the Clean Water Act and related state programs; the Emergency Planning and Community Right-to-Know Act, the Resource Conservation and Recovery Act and state and local hazardous waste regulations; the National Environmental Policy Act and the California Environmental Quality Act; the Endangered Species Act; the National Historic Preservation Act; the Antiquities Act; and the Comprehensive Environmental Response, Compensation and Liability Act.

Environmental Management System

LLNL established its Environmental Management System (EMS) to meet the requirements of the International Organization for Standardization (ISO) 14001:1996 in June 2004. In June 2006, LLNL upgraded its EMS to meet the requirements of ISO 14001:2004. In late 2006, the EMS was extended to the directorate level.

To further implement LLNL's EMS, a Multi-Directorate Consortium was formed to provide a forum for identifying common environmental issues. The Consortium was a venue for presentations on shared chemical usage, energy topics, and office paper use and reduction. During 2007, six directorates completed one or more directorate environmental management plans (EMPs) and the EMPs developed to address Lab-wide environmental aspects during 2006 are still in progress or contain an ongoing component.

Pollution Prevention

A strong Pollution Prevention (P2) Program is an essential element of LLNL's EMS. The P2 Team is responsible for P2 program stewardship and maintenance, waste stream analysis, waste generation reporting, and coordination of institutional P2 programs and activities.

Two LLNL projects were selected by NNSA/Headquarters to receive 2007 Environmental Stewardship awards. The first award was for the Space Action Team's "Assets for Value" process, which allows the reuse/salvage value of materials to be included as an offset to bids for decontamination and demolition. The second award was to Fleet Management for the construction and operation of an E85 fuel dispensing station.

LLNL also conducted activities to promote employee awareness of P2, including the annual Earth Expo held in April to coincide with Earth Day, articles in the LLNL newspaper, and training for procurement staff.

Air Monitoring

LLNL operations involving radioactive materials had minimal impact on ambient air during 2007. Estimated nonradioactive emissions are small compared to local air district emission criteria.

Releases of radioactivity to the environment from LLNL operations occur through stacks and from diffuse area sources. In 2007, radioactivity released to the atmosphere was monitored at six facilities on the Livermore site and one at Site 300. In 2007, 0.57 TBq (15.4 Ci) of tritium was released from the Tritium Facility, and 1.7 GBq of tritium (46 mCi) was released from the Decontamination and Waste Treatment Facility. The Contained Firing Facility at Site 300 had 2.1 kBq (57 nCi) of depleted uranium released in particulate form in 2007. None of the other facilities monitored for gross alpha and gross beta radioactivity had emissions in 2007.

The magnitude of nonradiological releases (e.g., reactive organic gases/precursor organic compounds, nitrogen oxides, carbon monoxide, particulate matter, sulfur oxides) is estimated based on specifications of equipment and hours of operation. Estimated releases in 2007 for the Livermore site were of similar levels to those in 2006; estimated releases at Site 300 were higher in 2007 than in 2006 due primarily to the required periodic preventative maintenance of emergency stand-by diesel generators. Nonradiological releases from LLNL continue to be a very small fraction of releases from all sources in the Bay Area or San Joaquin County.

In addition to air effluent monitoring, LLNL samples ambient air for tritium, radioactive particles, and beryllium. Some samplers are situated specifically to monitor areas of known contamination; some monitor potential exposure to the public; and others, distant from the two LLNL sites, monitor the natural background. In 2007, ambient air monitoring data confirmed estimated releases from monitored stacks and were used to determine source terms for resuspended plutonium-contaminated soil and tritium diffusing from area sources at the Livermore site and

resuspended uranium-contaminated soil at Site 300. In 2007, radionuclide particulate, tritium, and beryllium concentrations in air at the Livermore site and in the Livermore Valley were well below the levels that would cause concern for the environment or public health.

Water Monitoring

Monitoring of various categories of water is carried out to determine whether any radioactive or nonradioactive constituents released by LLNL might have a negative impact on public health and the environment. Data indicate LLNL has good control of its discharges to the sanitary sewer, and discharges to the surface water and groundwater do not have any apparent environmental impact.

Permits, including one for discharging treated groundwater from the Livermore site Ground Water Project, regulate discharges to the City of Livermore sanitary sewer system. During 2007, no discharges to the sanitary sewer exceeded any effluent limits for radioactive materials, and all the values were less than 2% of the allowed limits. For nonradioactive materials, there was one excursion outside the permissible pH range (see **Section 5.1.1.2**); all other constituents were less than 20% of the allowed limits. All discharges to the Site 300 sewage evaporation and percolation ponds were within permitted limits, and groundwater monitoring showed no measurable impacts.

Storm water is sampled for constituents such as radioactivity, metals, oxygen, dioxins, polychlorinated biphenyls (PCBs), and nitrate both upstream and downstream from both the Livermore site and Site 300. In 2007, no acute or chronic toxicity was seen in runoff, and data showed that the quality of Livermore site storm water effluent was similar to that entering the site (influent). At Site 300 in 2007, data continued to show that most constituents are transported sorbed to suspended sediments and that concentrations remained below levels of environmental concern.

Extensive monitoring of groundwater occurs at and near the Livermore site and Site 300. Groundwater from wells downgradient from the Livermore site is analyzed for pesticides, herbicides, radioactivity, nitrates, and hexavalent chromium. To detect any off-site contamination quickly, the well water is sampled in the uppermost water-bearing layers. Near Site 300, monitored constituents in off-site groundwater include explosives residue, nitrate, perchlorate, metals, volatile and semivolatile organic compounds, tritium, uranium, and other (gross alpha and beta) radioactivity. With the exception of volatile organic compounds (VOCs) in wells monitored for CERCLA compliance, the constituents of all off-site samples collected at both the Livermore site and Site 300 in 2007 were below allowable limits for drinking water.

Surface waters and drinking water are analyzed for tritium and gross alpha and gross beta radioactivity. In the Livermore Valley, the maximum tritium activity was less than 1% of the drinking water standard, and the maximum gross alpha and gross beta measurements were less than 35% of their respective drinking water standards. For Lake Haussmann (formerly called the Drainage Retention Basin) on the Livermore site, levels of gross alpha, gross beta, tritium, metals, and pesticides were below discharge limits, and organics and PCBs were below detection

limits. Aquatic bioassays for acute and chronic toxicity showed no effects in water discharged from Lake Haussmann. At Site 300, maintenance and the operation of drinking water and cooling systems resulted in discharges that were below permitted limits.

Terrestrial Radiological Monitoring

The impact of LLNL operations on surface soil, sediment, and vadose zone soils in 2007 was insignificant. Soils and sediments are analyzed for plutonium, gamma-emitting radionuclides, tritium, total and soluble metals, and PCBs as appropriate. Plutonium concentrations at the Livermore Water Resources Division (formerly called the Livermore Water Reclamation Plant) continued to be high relative to other sampled locations, but even this concentration was only 1.5% of the screening level for cleanup recommended by the National Council on Radiation Protection (NCRP). At Site 300, soils are analyzed for gamma-emitting radionuclides and beryllium. In 2007, uranium-238 concentrations in soils at Site 300 were below NCRP-recommended screening levels. Beryllium concentrations were within the ranges reported since sampling began in 1991.

Vegetation and Livermore Valley wine were sampled for tritium. In 2007, the median concentrations in all off-site vegetation samples were below the lower limit of detection of the analytical method. The highest concentration of tritium in Livermore Valley wines sampled in 2007 was 0.3% of the drinking water standard.

LLNL's extensive network of thermoluminescent dosimeters and real-time sensors measure the natural terrestrial and cosmogenic background; in 2007, as in recent years, no impact from LLNL operations was detected.

Biota

Through monitoring and compliance activities in 2007, LLNL avoided most impacts to special status species and enhanced some habitats. LLNL studies, preserves, and tries to improve the habitat of five species at Site 300 that are covered by the federal or California Endangered Species Acts—California tiger salamander (*Ambystoma californiense*), California red-legged frog (*Rana aurora draytonii*), Alameda whipsnake (*Masticophus lateralis euryxanthus*), valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*), and the large-flowered fiddleneck (*Amsinckia grandiflora*)—as well as species that are rare and otherwise of special interest. At Site 300, LLNL monitors populations of birds and rare species of plants and also continues restoration activities for the four rare plant species known to occur at Site 300—the large-flowered fiddleneck, the big tarplant (*Blepharizonia plumosa*, also known as *Blepharizonia plumosa* subsp *plumosa*), the diamond-petaled poppy (*Eschscholzia rhombipetala*), and the round-leaved filaree (*Erodium macrophyllum*).

LLNL took several actions to control invasive species in 2007. Measures taken at the Livermore site to control bullfrogs, which are a significant threat to California red-legged frogs, included

dispatching adults, removing egg masses, and allowing part of Arroyo Las Positas to dry out in October 2007. Site 300's invasive species control efforts have been focused largely on dispatching feral pigs. In 2007, six feral pigs were dispatched.

The 2007 radiological doses calculated for biota at the Livermore site or Site 300 were far below screening limits set by DOE, even though highly conservative assumptions maximized the potential effect of LLNL operations on biota.

Radiological Dose

Annual radiological doses at the Livermore site and Site 300 in 2007 were found to be well below the applicable standards for radiation protection of the public. Dose calculated to the site-wide maximally exposed individual (SW-MEI) for 2007 was 0.031 μSv (0.0031 mrem) for the Livermore site and 0.035 μSv (0.0035 mrem) at Site 300. These doses are well below the federal National Emissions Standards for Hazardous Air Pollutants of 100 μSv (10 mrem) and are significantly less than the doses from natural background radiation (see **Section 7.3.4**). Four sources of tritium at LLNL contributed nearly 100% of the dose received by the SW-MEI. There were no unplanned releases of radionuclides to the atmosphere at the Livermore site or at Site 300.

Groundwater Remediation

Groundwater at both the Livermore site and Site 300 is contaminated from historical operations; the contamination, for the most part, is confined to each site. Groundwater at both sites is undergoing cleanup under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). Remediation activities removed contaminants from groundwater and soil vapor at both sites, and documentation and investigations continue to meet regulatory milestones.

At the Livermore site, contaminants include VOCs, fuel hydrocarbons, metals, and tritium, but only the VOCs in groundwater and saturated and unsaturated soils need remediation. VOCs are the main contaminant found at the nine Site 300 operable units (OUs). In addition, nitrate, perchlorate, tritium, high explosives, depleted uranium, organosilicate oil, and metals are found at one or more of the OUs.

In 2007, concentrations continued to decrease in most of the Livermore site VOC plumes due to active remediation and the removal of more than 318 kg of VOCs from both groundwater and soil vapor. VOC concentrations on the western margin of the site continued their decline, indicating effective hydraulic control of the boundary plumes. In the interior of the site, remediation activities, including soil vapor extraction, dual extraction, and groundwater extraction, have resulted in declines of VOC concentrations in source areas.

In 2007 at Site 300, perchlorate, nitrate, the high explosive RDX, and organosilicate oil were removed from groundwater in addition to about 62 kg of VOCs. Each Site 300 OU has a different profile of contaminants, but overall, groundwater and soil vapor extraction and natural attenuation continue to reduce the mass of contaminants in the subsurface. Cleanup remedies have been fully implemented and are operational at seven of the nine OUs at Site 300; cleanup remedies for one of the remaining units has been submitted and the Remedial Investigation/Feasibility Study for the other OU is scheduled for 2008.

Conclusion

The combination of surveillance and effluent monitoring, source characterization, and dose assessment showed that the radiological dose to the hypothetical, most-exposed member of the public caused by LLNL operations in 2007 was substantially less than the dose from natural background. Potential dose to biota was well below DOE screening limits. LLNL demonstrated good compliance with permit conditions for releases to air and to water. Analytical results and evaluations of air and various waters potentially impacted by LLNL operations showed minimal contributions from LLNL operations. Remediation efforts at both the Livermore site and Site 300 further reduced concentrations of contaminants of concern in groundwater and soil vapor.

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1. Introduction

Lawrence Livermore National Laboratory (LLNL) is a premier research laboratory that is part of the National Nuclear Security Administration (NNSA) within the U.S. Department of Energy (DOE). The DOE selected Lawrence Livermore National Security (LLNS) to manage and operate LLNL. The contract began October 1, 2007. The new management team includes Bechtel National, University of California, BWX Technologies (BWXT), Washington Group International, Battelle, and Texas A&M University.

As a national security laboratory, LLNL is responsible for ensuring that the nation's nuclear weapons remain safe, secure, and reliable. The Laboratory also meets other pressing national security needs, including countering the proliferation of weapons of mass destruction and strengthening homeland security, and conducts major research in atmospheric, earth, and energy sciences; bioscience and biotechnology; and engineering, basic science, and advanced technology. The Laboratory, with a staff of more than 8000, serves as a scientific resource to the U.S. government and a partner to industry and academia.

1.1 Location

LLNL consists of two sites—an urban site in Livermore, California, referred to as the "Livermore site"; and a rural experimental test site, referred to as "Site 300," near Tracy, California. See **Figure 1-1**.

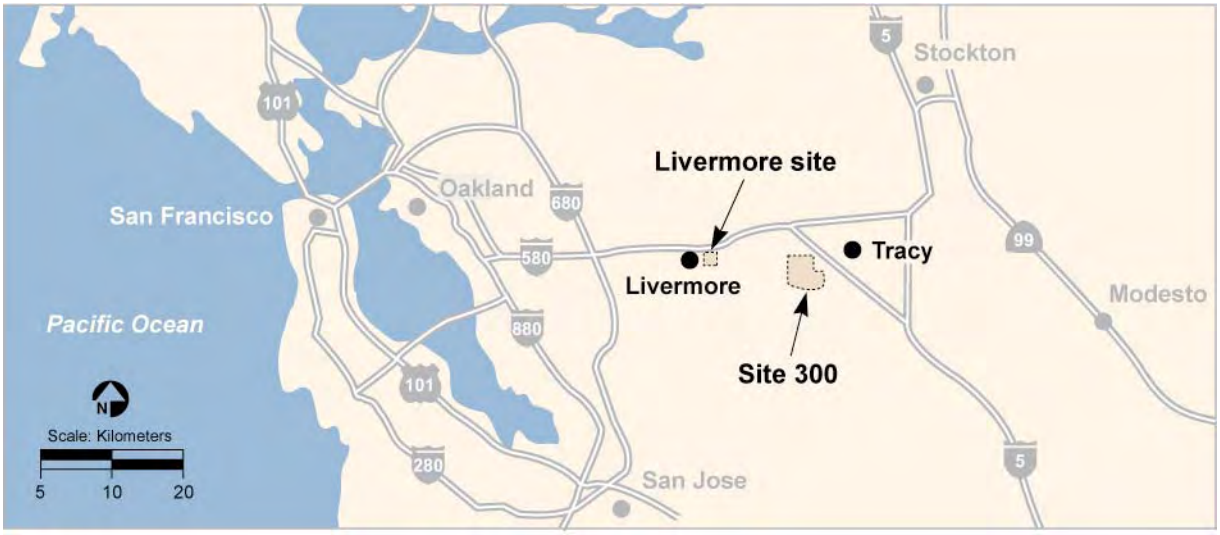

Figure 1-1. Location of the two LLNL sites—the Livermore site and Site 300.

The Livermore site is just east of Livermore, a city of about 80,000 in Alameda County. The site occupies 1.3 mi^2, including the land that serves as a buffer zone around most of the site.

Within an 50-mi radius of the Livermore site are communities such as Tracy and Pleasanton and the more distant (and more densely populated) cities of Oakland, San Jose, and San Francisco. Of the 7.1 million people within 50 mi of the Laboratory, only about 10% are within 20 mi.

Site 300, LLNL's Experimental Test Site, is located in the Altamont Hills of the Diablo Range and straddles the San Joaquin and Alameda county line. The site is 12 mi east of the Livermore site and occupies 10.9 mi^2.

The city of Tracy, with a population of over 80,000, is approximately 6 mi to the northeast (measured from the northeastern border of Site 300 to Sutter Tracy Community Hospital). Of the 6.2 million people who live within 50 mi of Site 300, 95% are more than 20 mi away in distant metropolitan areas such as Oakland, San Jose, and Stockton.

1.2 Meteorology

Meteorological towers at both the Livermore site and Site 300 continuously gather data including wind speed, wind direction, rainfall, humidity, solar radiation, and air temperature. Mild, rainy winters and warm-to-hot, dry summers characterize the climate at both sites. For a detailed review of the climatology for LLNL, see Gouveia and Chapman (1989). A new 52-m meteorological tower was installed at Site 300 in 2007; this new tower and the old 8-m tower in use since 1979 provided simultaneous measurements during 2007 for continuity and to observe any differences between the two tower locations. The old tower was retired in early 2008.

Both wind and rainfall exhibit strong seasonal patterns. Wind patterns at both sites tend to be dominated by the thermal draw of the warm San Joaquin Valley that results in wind blowing from the cool ocean toward the warm valley during the warm season, increasing in intensity as the valley heats up. During the winter, the wind blows from the northeast more frequently as cold, dense air spills out of the San Joaquin Valley. Approximately 55% of the seasonal rain at both sites falls in January, February, and March and approximately 80% falls in the five months from November through March, with very little rain falling during the warmer months. For a detailed review of rainfall at LLNL, see Bowen (2007). The meteorological conditions at Site 300 are modified by higher elevation and more pronounced topological relief. The complex topography of the site strongly influences local wind and temperature patterns.

The wind patterns, or wind roses, for the two towers at Site 300 are similar but they do show subtle differences. The data from the old tower indicates a distinct maximum from the west–southwest while the data from the new tower has the peak spread over the southwest and west–southwest sectors. Similarly the old tower data indicates a secondary peak of winds blowing from the northwest and north–northwest while the secondary peak at the new tower includes a slightly greater frequency of winds from adjacent sectors (west–northwest and north). Possible explanations for these subtle differences are that the new tower is located on grassy terrain and just downwind of higher terrain while the old tower is located on a small hill and therefore experiences less frictional effect from the ground. The new tower is also located at a slightly higher elevation and possibly receives more mixing from higher winds.

Temperature, rainfall, and wind speed data for the Livermore site and Site 300 towers during 2007 are summarized in **Table 1-1**. Annual wind data for the Livermore site and Site 300 are shown in **Figure 1-2**.

Table 1-1. Summary of temperature, rainfall, and wind speed data at the Livermore site and Site 300 during 2007.

	Livermore Site		Site 300 (old tower)		Site 300 (new tower)	
Temperature	**°C**	**°F**	**°C**	**°F**	**°C**	**°F**
Mean daily maximum	22.6	72.6	21.4	70.5	22.0	71.6
Mean daily minimum	7.0	44.6	12.2	54.0	11.6	52.9
Average	14.8	58.6	16.8	62.2	16.8	62.2
High	42.0	108	39.4	103	39.9	104
Low	–6.7[a]	20[a]	–2.8	27	–3.1	26
Rainfall	**cm**	**in.**	**cm**	**in.**	**cm**	**in.**
Total for 2007	21.7	8.53	18.8	7.40	17.9	7.04
Normal[b]	34.6	13.62	27.0	10.64	—[c]	—[c]
Wind	**m/s**	**mph**	**m/s**	**mph**	**m/s**	**mph**
Average speed	2.5	5.6	6.4	14.4	6.3	14.1
Peak gust speed	18.3	41	28.3	63	31.5	71

(a) Record low.

(b) Based on the mean, 1971–2000, at both sites.

(c) Normal values not available because of brief measurement history at new tower.

1.3 Topography

The Livermore site is located in the southeastern portion of the Livermore Valley, a prominent topographic and structural depression oriented east–west within the Diablo Range. The most prominent valley in the Diablo Range, the Livermore Valley is bounded on the west by Pleasanton Ridge and on the east by the Altamont Hills. The valley is approximately 14 mi long and varies in width generally between 2.5 and 7 mi. The valley floor is at its highest elevation of 720 ft above sea level along the eastern margin near the Altamont Hills and dips gradually to 300 ft at the southwestern corner. The valley floor is covered primarily by alluvial and floodplain deposits consisting of gravels, sands, silts, and clays with an average thickness of about 325 ft. Ephemeral waterways flowing through the Livermore site include Arroyo Seco along the southwestern corner and Arroyo Las Positas along the eastern and northern perimeters. See Karachewski et al. (2008) for a detailed discussion of the Livermore site hydrogeology.

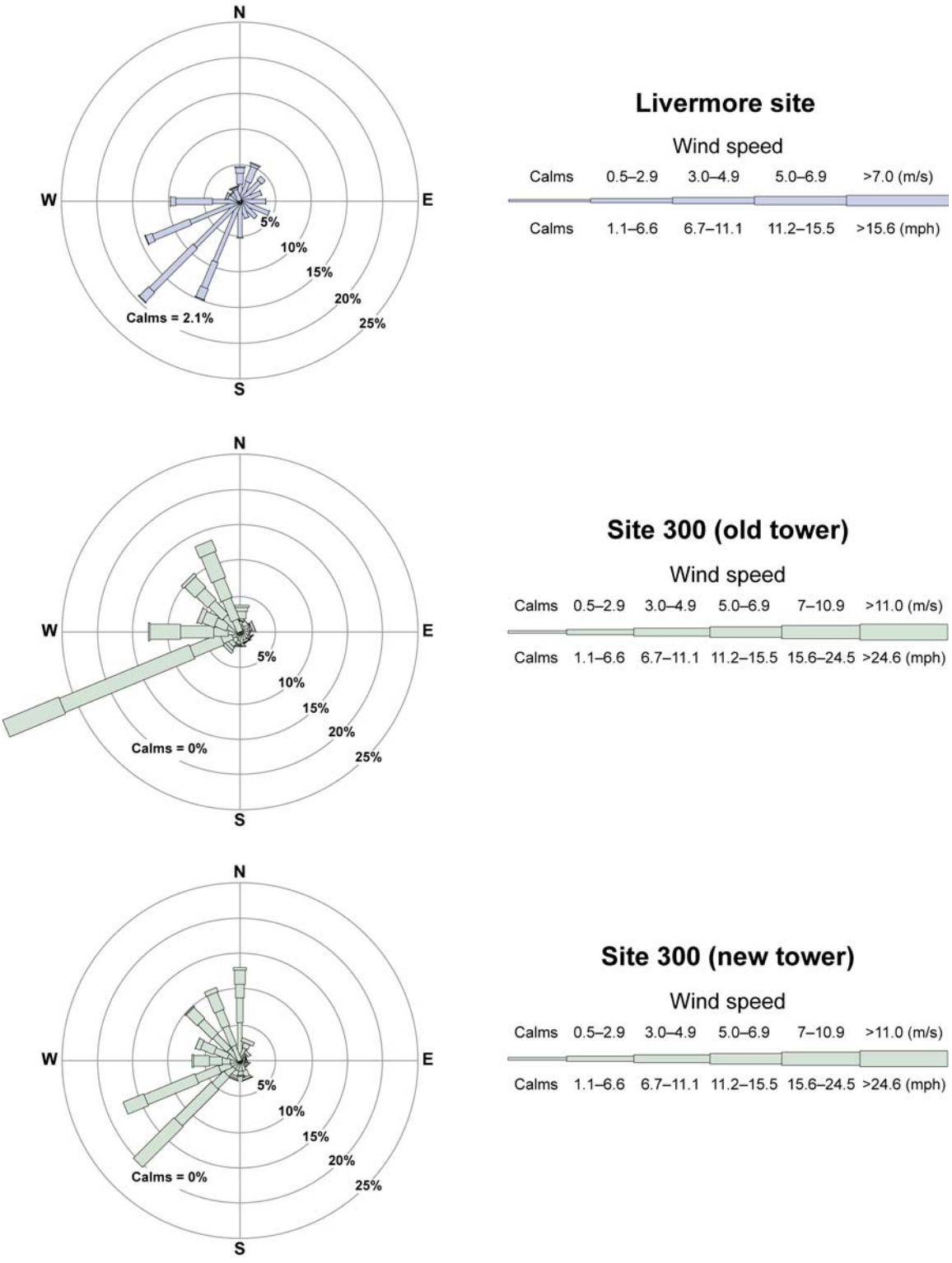

Figure 1-2. Wind roses showing wind direction and speed frequency at the Livermore site and Site 300 during 2007. The length of each spoke is proportional to the frequency at which the wind blows from the indicated direction. Different line widths of each spoke represent wind speed classes.

The topography of Site 300 is much more irregular than that of the Livermore site; a series of steep hills and ridges is oriented along a generally northwest–southeast trend and is separated by intervening ravines. The Altamont Hills, where Site 300 is located, are part of the California Coast Range Province and separate the Livermore Valley to the west from the San Joaquin Valley to the east. The elevation of Site 300 ranges from about 1740 ft above sea level at the northwestern corner of the site to approximately 490 ft in the southeastern portion. Corral Hollow Creek, an ephemeral stream that drains toward the San Joaquin Basin, runs along the southern and eastern boundaries of Site 300.

1.4 Hydrogeology

The Livermore Formation and overlying alluvial deposits contain the primary aquifers of the Livermore Valley groundwater basin. Natural recharge occurs primarily along the basin margins and arroyos during wet winters. In general, groundwater flows toward the central east–west axis of the valley and then westward through the central basin. Groundwater flow in the basin is primarily horizontal, although a significant vertical component probably exists along the basin margins under localized sources of recharge and near heavily used extraction or water production wells. Beneath the Livermore site, the depth to the water table varies from about 30 to 130 ft below the ground surface.

Site 300 is generally underlain by gently dipping sedimentary bedrock dissected by steep ravines. The bedrock is made up primarily of interbedded sandstone, siltstone, and claystone. Groundwater occurs primarily in the Neroly Formation upper and lower blue sandstone units and in the underlying Cierbo Formation. Significant groundwater is also locally present in permeable Quaternary alluvium valley fill and underlying decomposed bedrock, especially during wet winters. Much less groundwater is present within perched aquifers in the unnamed Pliocene nonmarine unit. Perched aquifers contain unconfined groundwater separated from an underlying main body of groundwater by impermeable layers; normally these perched zones are laterally discontinuous. Because water quality is generally poor and yields are low, these perched water-bearing zones do not meet the State of California criteria for aquifers that are potential water supplies. Recharge occurs predominantly in locations where saturated alluvial valley fill is in contact with underlying permeable bedrock or where permeable bedrock strata crop out along the canyon bottom because of structure or topography. Local recharge also occurs on hilltops, creating some perched water-bearing zones. Low rainfall, high evapotranspiration, steep topography, and intervening aquitards generally preclude direct vertical recharge of the deeper bedrock aquifers.

The thick Neroly Formation lower blue sandstone, stratigraphically near the base of the formation, generally contains confined groundwater. Wells located in the western part of the Site 300 General Services Area pump water from this aquifer, which is used for drinking and process supply.

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2. Compliance Summary

LLNL activities comply with federal, state, and local environmental regulations, internal requirements, Executive Orders, and applicable DOE orders. This chapter provides an overview of LLNL's compliance programs and activities during 2007. **Table 2-1** is a summary of active permits in 2007 at the Livermore site and Site 300. **Table 2-2** lists inspections, tours, and findings from these at both LLNL sites in 2007.

2.1 Environmental Restoration and Waste Management

2.1.1 Comprehensive Environmental Response, Compensation and Liability Act

Ongoing remedial investigations and cleanup activities at LLNL fall under the jurisdiction of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), Title I of the Superfund Amendments and Reauthorization Act (SARA). CERCLA is commonly referred to as the Superfund law.

CERCLA compliance activities for the Livermore site and Site 300 are summarized in **Sections 2.1.1.1** and **2.1.1.2**. Community relations activities conducted by DOE/LLNL are also part of these projects. See **Chapter 8** for more information on the activities and findings of the investigations.

2.1.1.1 Livermore Site Ground Water Project

The Livermore site came under CERCLA in 1987 when it was placed on the National Priorities List. The Livermore Site Ground Water Project (GWP) complies with provisions specified in a Federal Facility Agreement (FFA) entered into by the U.S. Environmental Protection Agency (EPA), DOE, the California EPA's Department of Toxic Substances Control (DTSC), and the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB). As required by the FFA, the GWP addresses compliance issues by investigating potential contamination source areas (e.g., suspected old release sites, solvent-handling areas, leaking underground tank systems), monitoring water quality through an extensive network of wells, and remediating contaminated soil and groundwater. The primary soil and groundwater contaminants (constituents of concern) are common volatile organic compounds (VOCs), primarily TCE and PCE.

Significant GWP restoration activities in 2007 included installing one dual (groundwater and soil vapor) extraction well and two soil vapor extraction wells, and focusing efforts on enhanced source area remediation. LLNL met all regulatory and DOE milestones on schedule.

Treatment Facilities. In 2007, LLNL operated 29 groundwater treatment facilities. The 95 groundwater extraction wells and 27 dual extraction wells produced nearly 1.1 billion L of groundwater and removed approximately 71 kg of VOCs. Since remediation began in 1989, more than 12.9 billion L of groundwater have been treated, resulting in the removal of more than 1317 kg of VOCs.

Table 2-1. Active permits in 2007 at the Livermore site and Site 300.

Type of permit	Livermore site[a]	Site 300[a]
Hazardous waste	EPA ID No. CA2890012584. Hazardous Waste Facility Permit Number 99-NC-006 (RCRA Part B permit)—to operate hazardous waste management facilities. Registered Hazardous Waste Hauler authorized to transport wastes from Site 300 to the Livermore site. Conditionally Exempt Specified Wastestream permit to mix resin in Unit CE231-1. Conditional Authorization Permit to operate sludge dewatering unit in Building 322A.	EPA ID No. CA2890090002. Hazardous Waste Facility Permit—CSA (Building 883) and EWSF. Hazardous Waste Facility Permit —EWTF. Hazardous Waste Facility Post-Closure Permit—Building 829 High Explosives Open Burn Treatment Facility.
Medical waste	ACDEH issued a permit that covers medical waste generation and treatment activities for the eight BSL 2 facilities, and the BSL 3 facility at Building 368.	NA
Air	BAAQMD issued 177 permits for operation of various types of equipment. BAAQMD issued a SMOP to ensure the Livermore site does not exceed federal Clean Air Act Title V emission limits for regulated pollutants. CARB issued 5 permits for the operation of portable diesel air compressors and generators.	SJVAPCD issued 36 permits for operation of various types of equipment. SJVAPCD approved a Prescribed Burn Plan for the burning of 2042.7 acres of grassland. BAAQMD issued 1 permit for the operation of an emergency diesel generator. BAAQMD approved a Prescribed Burn Plan for the burning of 139.1 acres of grassland.
Storage tanks	Seven operating permits covering 10 underground petroleum product and hazardous waste storage tanks.	One operating permit covering three underground petroleum product tanks assigned individual permit numbers.
Sanitary sewer	Discharge Permit 1250[b] for discharges of wastewater to the sanitary sewer. Permit 1510G for discharges of groundwater from restoration.	WDR No. 96-248 for operation of sewage evaporation and percolation ponds.
Water	WDR No. 88-075 for discharges of treated groundwater from Treatment Facility A to recharge basin.[c] NPDES Permit No. CA0030023 for discharges of storm water associated with industrial activities and low-threat nonstorm water discharges to surface waters. NPDES General Permit No. CAS000002; Soil Reuse Project (201C349339); National Ignition Facility (201C349114); A-4 & Z-5S Parking Lots (201C333137); D-4 Parking Lot (201C342783); and E-9 Parking Lot (201C349049); for discharges of storm water associated with construction activities affecting 0.4 hectares (1 acre) or more. FFA for groundwater investigation/remediation.	WDR No. 93-100 for post-closure monitoring requirements for two Class I landfills. WDR No. 96-248 for discharges to equipment wastewater percolation pits. NPDES General Permit No. CAS000001 for discharge of storm water associated with industrial activities. NPDES Regional General Permit No. CAG995001 for large volume discharges from the drinking water system. FFA for groundwater investigation/remediation. 34 registered Class V injection wells.

Note: See the **Acronyms and Glossary** section for acronym definitions.

(a) Numbers of permits are based on actual permitted units or activities maintained and/or renewed by LLNL during 2007.

(b) Permit 1250 includes some wastewater generated at Site 300 and discharged at the Livermore site.

(c) Recharge basins referenced in WDR Order No. 88-075 are located south of East Avenue within Sandia National Laboratories/California boundaries. The discharge no longer occurs; however, the agency has not rescinded the permit.

Table 2-2. Inspections of Livermore site and Site 300 by external agencies in 2007.

Site	Medium	Description	Agency	Date	Finding
Livermore site	Waste	Hazardous waste facilities Compliance Evaluation Inspection (CEI)	DTSC	9/26/07 10/9/07–10/11/07	Received one minor violation for an incorrect TSDF date on LLNL's operating record (Container Contents Report) that did not reflect the container in the Building 693 roll-off bin with the oldest TSDF date. The correct TSDF date was placed on the roll-off bin and no further action is required.
		Hazardous waste generator areas (SAAs and WAAs), Conditionally Exempt Specified Wastestream for resin mixing unit in CE231-1, Conditional Authorization Unit in Building 322A, Hazardous Materials Release Response Plans and Inventories (Business Plans) and CalARP Program	ACDEH-CUPA	7/25/07 8/9/07 9/5/07 9/6/07 9/10/07 9/12/07	No violations were issued during the inspection close-out meeting. LLNL has not yet received the final inspection report.
		Medical waste	ACDEH	11/28/07	No violations
	Discarded Major Appliances	Certified Appliances	ACDEH	1/18/07	No violations
	Waste Tires	Waste Tire Management Inspection	ACDEH	1/17/07	No violations
	Air	39 emission sources	BAAQMD	7/26/07 12/13/07 12/19/07	No violations
		Asbestos	BAAQMD	10/11/07	No violations
		SMOP	BAAQMD	3/1/07	No violations
	Sanitary sewer	Annual compliance sampling	WRD	10/1/07 – 10/2/07	No violations
		Categorical sampling/inspection Building 153	WRD	10/10/07	No violations
		Categorical sampling/inspection Building 321C		10/16/07	No violations
		Quarterly BOD/TSS Monitoring	WRD	3/9/07	Sampling for billing purposes, not compliance
				6/7/07	Sampling for billing purposes, not compliance
				9/18/07	Sampling for billing purposes, not compliance
				11/7/07	Sampling for billing purposes, not compliance

Table 2-2 (cont.). Inspections of Livermore site and Site 300 by external agencies in 2007.

Site	Medium	Description	Agency	Date	Finding
Livermore site (cont.)	Storage tanks	Compliance with underground storage tank requirements and operating permits	ACDEH	9/10/07 9/17/07	No violations
	Pesti-cides	Pest control records inspections	ACCDA	11/14/07	No violations
Site 300	Waste	Permitted hazardous waste operational facilities (EWTF, EWSF, Building 883 CSA), RCRA-closed, post-closure permit-ted facility Building 829 Open Burn Facil-ity, and a review of hazardous waste-related documentation (CEI).	DTSC	3/19/07–3/20/07	DTSC issued one violation for failure to provide the specified number of training hours to an LLNL Site 300 Field Technician for Basic Respirator Training (course #HS4610) and Self-Contained Breathing Apparatus Training (course #HS4360). LLNL provided the additional training hours on August 2, 2007, and submitted a corrective action letter to DTSC on August 28, 2007. DTSC reviewed the corrective action letter and deter-mined that no further action would be required. The DTSC corrective action response letter was dated October 3, 2007.
		Hazardous waste generator area inspec-tion (WAAs, SAAs and hazardous waste-related related records for hazardous waste generator activities only).	SJCEHD-CUPA	6/25/07	During an inspection of the machine shop in Building 875, one violation was issued for failure to make a hazardous waste determination of ma-chine grinding waste generated from metal grinding operations. The corrective action letter committed to managing metal grind waste as either hazardous waste in compliance with 22 CCR Division 4.5, Chapter 11 and 22 CCR Division 4.5, Chapter 12, or scrap metal as defined in 22 CCR Division 4.5, Chapter 10, Article 2, 66260.10. The corrective action letter and Return to Compliance Certification were submitted to SJCEHD-CUPA on July 25, 2007.
	Vehicle	Biennial transportation terminal inspection	CHP	1/17/07	No violations
	Air	36 emission sources	SJVAPCD	4/3/07	No violations
	Water	Permitted operations	CVRWQCB	4/23/07 10/29/07	No violations
	Storage tanks	Compliance with underground storage tank requirements and operating permits	SJCEHD	9/12/07 9/19/07	No violations

Note: See the **Acronyms and Glossary** section for acronym definitions.

In 2007, LLNL also operated 9 soil vapor treatment facilities. The 31 soil vapor extraction wells and 27 dual extraction wells produced nearly 1.5 million m^3 of soil vapor, and the treatment facilities removed more than 247 kg of VOCs. Since initial operation, more than 8.9 million m^3 of soil vapor have been extracted and treated, removing over 1300 kg of VOCs from the subsurface.

Community Relations. Livermore site community relations activities in 2007 included communication and meetings with neighbors and local, regional, and national interest groups and other community organizations; public presentations; maintenance of information repositories and an administrative record; tours of site environmental activities; and responses to public and news media inquiries. In addition, DOE/LLNL met with members of Tri-Valley Communities Against a Radioactive Environment (Tri-Valley CAREs) and the organization's scientific advisor as part of the activities funded by an EPA Technical Assistance Grant (TAG). Community questions were also addressed via electronic mail, and project documents, letters, and public notices were posted on a public website: http://www-envirinfo.llnl.gov.

2.1.1.2 Site 300 CERCLA Project

Remedial activities are ongoing at Site 300, which became a CERCLA site in 1990 when it was placed on the National Priorities List. Remedial activities are overseen by the EPA, the Central Valley Regional Water Quality Control Board (CVRWQCB), and DTSC, under the authority of an FFA for the site. Contaminants of concern at Site 300 include VOCs (primarily TCE), high explosive compounds, tritium, depleted uranium, silicone-based oils, nitrate, perchlorate, polychlorinated biphenyls, dioxins, furans, and metals. The contaminants present in environmental media vary within the different environmental restoration operable units (OUs) at the site. See Webster-Scholten (1994), and Ferry et al. (1999) for background information on LLNL environmental characterization and restoration activities at Site 300. See Ferry et al. (2006) for the current status of cleanup progress for sites that were remediated under an Interim Site-Wide Record of Decision (U.S. DOE 2001). In 2007, LLNL met all regulatory and DOE milestones on schedule. The Site-Wide Record of Decision for Site 300 establishing final cleanup actions and standards is scheduled for completion in 2008.

Treatment Facilities and Field Investigations. During 2007, LLNL operated 15 groundwater and 5 soil vapor treatment facilities at Site 300. The 40 groundwater extraction wells and 18 dual phase extraction wells extracted about 34 million L of groundwater during 2007. The 18 dual phase extraction wells and 2 soil vapor extraction wells together removed 1.5 million m^3 of soil vapor.

In 2007, the Site 300 treatment facilities removed about 62 kg of VOCs, 0.1 kg of perchlorate, 390 kg of nitrate, 0.16 kg of the high explosive compound RDX, and 0.029 kg of silicone-based oil. Since remediation efforts began in 1990, more than 1351 million L of groundwater and approximately 9 million m^3 of soil vapor have been treated, removing about 510 kg of VOCs, 0.7 kg of perchlorate, 5300 kg of nitrate, 0.94 kg of RDX, and 9.4 kg of silicone-based oil.

During 2007, the following field activities were completed by agreed-upon regulatory due dates:

- Modification of the B830-DISS groundwater treatment system in the Building 832 Canyon OU.
- Modification of the B854-PRX groundwater treatment system in the Building 854 OU.

In 2007, 16 boreholes were drilled at Site 300—one was drilled to collect soil and rock for chemical analysis, 3 were completed as extraction wells for groundwater treatment systems, and 12 were completed as monitoring wells for tracking of groundwater contaminant plumes.

Community Relations. The Site 300 CERCLA Project maintains continuing communications with the community of Tracy and nearby neighbors. Community relations activities in 2007 included maintenance of information repositories and an administrative record; participation in community meetings and workshops; tours of site environmental activities; offsite, private, well-sampling activities; mailings to stakeholders; and providing responses to public and news media inquiries. LLNL hosted TAG meetings with Tri-Valley CAREs to provide a forum for focused discussions on CERCLA activities at Site 300. A public workshop and meeting were held in Tracy for the Site-Wide Proposed Plan for the Remediation of Site 300 on February 16, 2007, and June 20, 2007, respectively.

2.1.2 Emergency Planning and Community Right-to-Know Act and Toxics Release Inventory Report

Title III of SARA, known as the Emergency Planning and Community Right-to-Know Act (EPCRA), requires owners and operators of facilities who handle certain hazardous chemicals on site to provide information on the release, storage, and use of these chemicals to organizations responsible for emergency response planning. Executive Order 13423, Strengthening Federal Environmental, Energy, and Transportation Management, directs all federal agencies to comply with the requirements of the EPCRA, including SARA, Section 313, the Toxic Release Inventory (TRI) Program.

On June 11, 2007, LLNL submitted to DOE/NNSA the TRI Form R for lead, detailing environmental release estimates for Site 300. Form R is used for reporting TRI chemical releases and includes information about waste management and waste minimization activities. The data on lead release estimates show a 5.2% decline from the previous reporting year; this decline will eventually plateau as activities reach their minimum levels. EPCRA requirements and LLNL compliance are summarized in **Table 2-3.**

2.1.3 Resource Conservation and Recovery Act and Related State Laws

The Resource Conservation and Recovery Act (RCRA) provides the framework at the federal level for regulating solid wastes, including wastes designated as hazardous. The California Hazardous Waste Control Act (HWCA) and California Code of Regulations (CCR) Title 22 set requirements for managing hazardous wastes and implementing RCRA in California. LLNL works with DTSC to comply with these regulations and obtain hazardous waste permits.

Table 2-3. Compliance with EPCRA.

EPCRA section	Brief description of requirement	LLNL action
302	Notify SERC of presence of extremely hazardous substances.	Originally submitted 5/87.
303	Designate a facility representative to serve as emergency response coordinator.	Update submitted 3/23/07.
304	Report releases of certain hazardous substances to SERC and LEPC.	No reportable releases in 2007.
311	Submit MSDSs or chemical list to SERC, LEPC, and Fire Department.	Update submitted 3/23/07.
312	Submit hazardous chemical inventory to local administering agency (county).	Submitted to San Joaquin and Alameda counties on 1/08/07 and 3/1/07, respectively.
313	Submit Form R to U.S. EPA and California EPA for toxic chemicals released above threshold levels.	Form R for lead for Site 300 submitted to DOE 6/11/07; DOE forwarded it to U.S. EPA and California EPA 6/27/07.

The hazardous waste management facilities at the Livermore site consist of permitted units in Area 612 and Buildings 693, 695, and 696 of the Decontamination and Waste Treatment Facility (DWTF). Permitted waste management units include container storage, tank storage, and various treatment processes (e.g., wastewater filtration, blending, and size reduction). Final closure was granted by the DTSC for Area 514, and closure approval for the Building 233 container storage unit (CSU) is expected once LLNL submits the Closure Report to the DTSC. LLNL also expects to receive DTSC's approval of the Building 419 Closure Plan during fiscal year 2008. During 2006/2007, LLNL submitted several permit modification requests to DTSC that have all been approved and are being implemented, including six Class 2 permit modifications.

The hazardous waste management facilities at Site 300 consist of three operational RCRA-permitted facilities. The Explosives Waste Storage Facility (EWSF) and the Explosives Waste Treatment Facility (EWTF) are permitted to store and treat explosives waste, respectively. The Building 883 container storage area (CSA) is permitted to store routine facility-generated waste such as spent acids, bases, contaminated oil, and spent solvents. Site 300 has one post-closure permit for the RCRA-closed Building 829 High Explosives Burn Pits. LLNL is currently in the process of renewing the hazardous waste facility permit for EWSF, EWTF, and Building 883 CSA. The Building 829 permit will not expire until April 2, 2013. Transportation of hazardous or mixed waste over public roads occurs by DTSC-registered transporters. DTSC issued hazardous waste transporter registration #1351 to LLNS on October 16, 2007.

2.1.4 Hazardous Waste Source Reduction and Management Review Act

The California Hazardous Waste Source Reduction and Management Review Act of 1989 (Senate Bill 14), requires LLNL to complete a Source Reduction Plan and Summary Report every four years. LLNL waste streams over five percent (by weight) of the total routine regulated waste were evaluated for waste reduction opportunities, and all extremely hazardous waste streams were

evaluated. The Pollution Prevention (P2) Team contributed data from both LLNL sites to a multiple-site plan developed for all DOE California sites. A combined report was submitted by DOE in 2007 for the reporting year 2006.

2.1.5 California Medical Waste Management Act

All LLNL medical waste management operations are conducted in accordance with the California Medical Waste Management Act (CMWMA). The program is administered by the California Department of Health Services (DHS) and is enforced by the Alameda County Department of Environmental Health (ACDEH). LLNL's medical waste permit is renewed on an annual basis and covers medical waste generation and treatment activities for the eight Biosafety Level (BSL) 2 facilities, and the BSL 3 facility at Building 368.

2.1.6 Radioactive Waste and Mixed Waste Management

LLNL manages radioactive waste and mixed waste in compliance with applicable sections of DOE Order 435.1, and the LLNL-developed *Radioactive Waste Management Basis for the Lawrence Livermore National Laboratory* (LLNL 2006), which summarizes radioactive waste management controls relating to waste generators and treatment and storage facilities. LLNL does not release to the public any property with residual radioactivity above the limits specified in DOE Order 5400.5. Excess property of this type is either transferred to other DOE facilities for reuse or transferred to LLNL's Radioactive and Hazardous Waste Division for disposal.

2.1.7 Federal Facility Compliance Act

LLNL is continuing to work with DOE to maintain compliance with the Federal Facilities Compliance Act (FFCA) Site Treatment Plan (STP) for LLNL, which was signed in February 1997. LLNL completed 36 milestones during 2007, and of those, 14 had due dates beyond 2007 (ranging from 2008 to 2011).

LLNL requested, and was granted, extensions for two additional milestones to allow LLNL time to pursue alternative treatment options for 1.7 m^3 of waste.

LLNL removed approximately 111 m^3 of mixed waste from the STP in 2007. An additional 47 m^3 of newly generated mixed waste was added to the STP, reflecting an overall reduction of 63.8 m^3 of mixed waste being stored by LLNL.

Reports and certification letters were submitted to DOE as required. LLNL continued the use of available commercial treatment and disposal facilities that are permitted to accept LLNL mixed waste. These facilities provide LLNL greater flexibility in pursuing the goals and milestones set forth in the STP.

2.1.8 Toxic Substances Control Act

The Federal Toxic Substances Control Act (TSCA) and implementing regulations found in Title 40 of the Code of Federal Regulation, Parts 700–789 (40 CFR 700-789) govern the uses of newly developed chemical substances and TSCA-governed waste. All TSCA-regulated waste was disposed of in accordance with TSCA, state, and local disposal requirements with one exception.

Radioactive polychlorinated biphenyl (PCB) waste is currently stored at one of LLNL's hazardous waste storage facilities until an approved facility accepts this waste for final disposal.

2.2 Air Quality and Protection

2.2.1 Clean Air Act

All activities at LLNL are evaluated to determine the need for air permits. Air permits are obtained from the Bay Area Air Quality Management District (BAAQMD) for the Livermore site and from the San Joaquin Valley Air Pollution Control District (SJVAPCD) and/or BAAQMD for Site 300. Both agencies are overseen by the California Air Resources Board (CARB), which oversees statewide permitting for portable diesel fuel-driven equipment such as portable generators and portable air compressors.

In 2007, LLNL operated 182 permitted air emission sources at the Livermore site and 37 permitted air emission sources at Site 300. In addition, the Livermore site continues to maintain a Synthetic Minor Operating Permit (SMOP), which was issued by the BAAQMD in 2002, to ensure the Livermore site does not emit regulated air pollutants in excess of federal Clean Air Act (CAA) Title V limits. Therefore, LLNL is able to demonstrate that it does not have any major sources of air pollutant emissions per 40 CFR 70.2.

LLNL eliminated a Freon vapor degreaser that had the potential of emitting 1.43 MT of the "greenhouse gas" Freon 113, annually; 1.43 MT of Freon 113 is equivalent to 7,007 MT of carbon dioxide. LLNL also eliminated three diesel-powered generators and installed exhaust filters with a verified 85% particulate capture capability on four diesel-powered generators. The elimination and modification of the seven generators significantly reduced the combustion pollutants emitted from the Livermore site by the diesel-powered generator fleet.

In May 2007, LLNL was granted a BAAQMD Permit to Operate an alternative fuel, E85, dispensing facility at the Livermore site. E85 fuel is a blend of 85% ethanol and 15% unleaded gasoline fuel, and meets Executive Order 13423 to increase the total fuel consumption that is non-petroleum-based by 10 % annually, as well as meets the intent of the proposed DOE Order 430.2B. In 2007, LLNL dispensed 41,893 gallons of E85 fuel.

2.2.2 National Emission Standards for Hazardous Air Pollutants, Radionuclides

To demonstrate compliance with 40 CFR Part 61, Subpart H (NESHAPs for radiological emissions from DOE facilities), LLNL monitors certain air release points and evaluates the maximum possible dose to the public. The *LLNL NESHAPs 2007 Annual Report* (Bertoldo et al. 2008), submitted to EPA, reported that the estimated maximum radiological doses that could have been received by a member of the public in 2007 were 0.031 μSv (0.0031 mrem) for the Livermore site and 0.035 μSv (0.0035 mrem) for Site 300. The totals are well below the 100 μSv/y (10 mrem/y) dose limits defined by the NESHAPs regulations.

2.3 Water Quality and Protection

LLNL complies with requirements of the federal Clean Water Act (CWA), Safe Drinking Water Act (SDWA), and Health and Safety Code; the California Aboveground Petroleum Storage Act, Water Code, and Health and Safety Code; and City of Livermore ordinances, by complying with regulations and obtaining permits issued by several agencies whose mission it is to protect water quality.

LLNL complies with the requirements of National Pollutant Discharge Elimination System (NPDES) and Waste Discharge Requirement (WDR) permits, and Water Quality Certifications issued by Regional Water Quality Control Boards (RWQCBs) and the State Water Resources Control Board (SWRCB) for discharges to waters of the U.S. and waters of the State. Discharges to the City of Livermore's sanitary sewer system are governed by permits issued by the Water Resources Division (WRD). The SDWA requires that LLNL register Class V injection wells with EPA, and LLNL obtains permits from the Army Corps of Engineers (ACOE) for work in wetlands and waters of the U.S.

The CWA and California Aboveground Petroleum Storage Act require LLNL to have and implement Spill Prevention Control and Countermeasure (SPCC) plans for aboveground, oil-containing containers. The ACDEH and the San Joaquin County Environmental Health Department (SJCEHD) also issue permits for operating underground storage tanks containing hazardous materials or hazardous waste (see **Table 2-1**). LLNL's permitted underground storage tanks, for which permits are required, contain diesel fuel, gasoline, and used oil; aboveground storage tanks, for which permits are not required, contain fuel, insulating oil, and process wastewater. In 2007, the new E85 alternative fuel dispensing facility, including the new underground tank system, was installed and went into operation.

2.4 Other Environmental Statutes

2.4.1 National Environmental Policy Act and Floodplains and Wetland Assessments

The National Environmental Policy Act (NEPA) is the U.S. government's basic environmental charter. When considering a proposed project or action at LLNL, DOE/NNSA must (1) consider how the action would affect the environment and (2) make certain that environmental information is available to public officials and citizens before decisions are made and actions are taken. The results of the evaluations and notice requirements are met through publication of "NEPA documents", such as environmental impact statements (EISs) and environmental assessments (EAs). In 2007, DOE/NNSA published or acted on:

- *Environmental Assessment for the Proposed Environmental Remediation at Lawrence Livermore National Laboratory Site 300 Pit 7 Complex* (DOE/EA-1569) in January, and its Finding of No Significant Impact (FONSI) in February

- *Draft Revised Environmental Assessment for the Proposed Construction and Operation of a Biosafety Level 3 Facility at Lawrence Livermore National Laboratory, Livermore, California* (DOE/EA-1442R) in March

There were no proposed actions at LLNL that required separate DOE floodplain or wetlands assessments under DOE regulations in 10 CFR Part 1022.

2.4.2 National Historic Preservation Act

The National Historic Preservation Act (NHPA) provides for the protection and preservation of historic properties that are significant in the nation's history. LLNL resources subject to NHPA consideration range from prehistoric archeological sites to remnants of LLNL's own history of scientific and technological endeavors. The responsibility to comply with the provisions of NHPA rests with DOE/NNSA as the lead federal agency in this undertaking. LLNL supports the agency's NHPA responsibilities with direction from DOE/NNSA.

In consultation with the State Historic Preservation Officer (SHPO), DOE/NNSA formally determined that five archaeological resources, five buildings, two historic districts, and selected objects in one building at LLNL are eligible for listing in the National Register of Historic Places (NRHP). To assist DOE and SHPO in developing an agreement as to how to manage the NRHP-eligible properties, LLNL prepared a draft Programmatic Agreement (PA), which includes a draft archaeological resources treatment plan and a draft historic buildings treatment plan as appendices. These plans describe specific resource management and treatment strategies that DOE/NNSA, in cooperation with LLNL, could implement to ensure that significant historic properties are managed in a manner that considers their historic value. As of 2007, SHPO was still reviewing the draft PA and treatment plans.

2.4.3 Antiquities Act of 1906

Provisions of the Antiquities Act provide for recovery of paleontological remains. No remains subject to the provisions of the Antiquities Act were identified in 2007.

2.4.4 Endangered Species Act and Sensitive Natural Resources

LLNL meets the requirements of the federal and state Endangered Species Act (ESA), the Eagle Protection Act, the Migratory Bird Treaty Act, and other applicable regulations as they pertain to endangered species, threatened species, and other special-status species (including their habitats) and designated critical habitats that exist at the LLNL sites. The following list highlights 2007 compliance activities.

- In June 2007, LLNL postponed the removal of power poles near the North Buffer Zone of the Livermore site to prevent potential impacts to nesting White-tailed Kites near the project site.
- In 2004, LLNL received a biological opinion (BO) from the U.S. Fish and Wildlife Service (USFWS) to construct a bridge along the access road to the Arroyo Mocho pump station and to improve fish passage at this site. On July 9, 2007, LLNL was issued an amendment to this

BO to remove boulders from the channel of Arroyo Mocho in the area directly below the pump station. In October 2007, LLNL biologists monitored the removal of the boulders.

- On February 26, 2007, LLNL submitted a revised site-wide biological assessment to the USFWS that summarizes previous Livermore site and Site 300 consultations. The original biological assessment was prepared as part of the 2005 *Final Site-wide Environmental Impact Statement for Continued Operations of Lawrence Livermore National Laboratory and Supplemental Stockpile Stewardship and Management Programmatic Environmental Impact Statement*.
- On December 13, 2007, LLNL was issued an amendment to the 1997 Arroyo Las Positas Biological Opinion to include potential impact to California red-legged frogs in drainages throughout the Livermore Site and to include the California tiger salamander.
- LLNL biologists monitored construction associated with the Pit 7 remediation project for potential impacts to California red-legged frogs and California tiger salamanders. This work was conducted under an amendment to the 2002 Biological Opinion for Routine Maintenance and Operations of Site 300, which was issued on July 12, 2007.

2.4.5 Federal Insecticide, Fungicide, and Rodenticide Act

LLNL complies with Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), which provides federal control of the distribution, sale, and use of pesticides, and requires that commercial users of pesticides are certified pesticide applicators. The California Department of Pesticide Regulation (DPR) has enforcement responsibility for FIFRA in California; DPR has in turn given enforcement responsibility to county departments of agriculture. All pesticides at LLNL are applied, stored, and used in compliance with FIFRA and other California, Alameda County, and San Joaquin County regulations governing the use of pesticides. The staff of the Landscape and Pest Management Shop at the Livermore site and the Laborer/Gardener Shop at Site 300 includes thirteen certified pesticide applicators. These shops ensure that all storage and use of pesticides at LLNL is in accordance with applicable regulations. LLNL also reviews pesticide applications to ensure they do not result in impacts to water quality or special status species.

2.5 Environmental Occurrences

Notification of environmental occurrences is required under a number of environmental laws and regulations as well as DOE Order 231.1A and DOE Manual 231.1-2. In 2007, six environmental incidents, summarized in **Table 2-4**, were reportable under DOE Order 232.1A.

Contributing Authors

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Table 2-4. Environmental Occurrences reported under the Occurrence Reporting System in 2007.

Date[(a)]	Occurrence category/group	Description
6/25/07	Significance Category SC4 Occurrence under Group 9(2) OR 2007-0033	LLNL received an NOV from SJCEHD for findings pertaining to the management of metal fines observed during the Site 300 annual CUPA inspection.
7/9/07	Significance Category SC4 Occurrence under Group 9(2) OR 2007-0034	LLNL received an NOV from the DTSC for a minor training violation following the March 19 and 20 inspection of RCRA-permitted facilities at Site 300.
8/5/07	Significance Category SC4 Occurrence under Group 10(2d) OR 2007-0035	The contents of a waste container stored at an RHWM facility over pressurized, causing the lid of the waste container to rupture.
8/26/07	Significance Category SCOE Occurrence under Group 1(1) OR 2007-0039	An Operational Emergency was declared when a wild land fire started at Site 300, burning approximately 25 to 40 acres of grass. Information gathered during the investigation indicated the fire was the result of a lightning strike.
12/3/07	Significance Category SC4 Occurrence under Group 9(2) OR 2007-0057	LLNL received a NOV from the DTSC for a finding observed during the annual CEI. A hazardous waste container was observed with the incorrect date on the hazardous waste label.
12/13/07	Significance Category SC3 Occurrence under Group 6B(3) OR 2007-0058	Radiological contamination was discovered on December 12, 2007, during an audit of the Building 321C yard RMA. On December 13, 2007, a review by the subject matter expert determined that the constituent contamination levels exceeded reportable levels.

(a) Date the occurrence was categorized, not discovered.

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3. Environmental Program Information

LLNL is committed to enhancing its environmental stewardship and to reducing any impacts its operations may have on the environment. This chapter described the lead organizations that support the LLNL's environmental stewardship and describes LLNL's Environmental Management System (EMS) and Pollution Prevention (P2) program.

3.1 Environmental Protection Program

Three organizations lead the environmental protection program and provide environmental expertise to the Laboratory: Environmental Protection Department (EPD), Radioactive and Hazardous Waste Management (RHWM) Division and Environmental Restoration Department (ERD). Spill response is also a key component of environmental protection.

3.1.1 Environmental Protection Department

EPD is responsible for environmental monitoring and environmental regulatory interpretation and implementation guidance in support of LLNL's programs. EPD prepares and maintains environmental plans, reports, and permits; maintains the environmental portions of the *Environment, Safety, and Health* (*ES&H) Manual*; informs management about pending changes in environmental regulations pertinent to LLNL; represents LLNL in day-to-day interactions with regulatory agencies and the public; develops and provides institutional environmental training; and assesses the effectiveness of pollution control programs. A principal part of EPD's mission is to work with LLNL programs to ensure that operations are conducted in a manner that limits environmental impact and that is in compliance with regulatory requirements. The EPD Department Head also serves as the LLNL EMS Coordinator and leads the EMS task force.

3.1.2 Radioactive and Hazardous Waste Management Division

RHWM manages all hazardous, radioactive, and mixed wastes generated at LLNL facilities in accordance with local, state, and federal requirements. RHWM processes, stores, packages, treats, and prepares waste for shipment and disposal, recycling, or discharge to the sanitary sewer. As part of its waste management activities, RHWM tracks and documents the movement of hazardous, mixed, and radioactive wastes from waste accumulation areas (WAAs), which are typically located near the waste generator, to final disposition; develops and implements approved standard operating procedures; decontaminates LLNL equipment; ensures that containers for shipment of waste meet the specifications of the U.S. Department of Transportation (DOT) and other regulatory agencies; responds to emergencies; and participates in the cleanup of potential hazardous and radioactive spills at LLNL facilities. RHWM prepares numerous reports in support of its mission including those required by regulation and various guidance and management plans.

RHWM meets regulations for the treatment of LLNL's mixed waste in accordance with the requirements of the FFCA. The schedule for this treatment is negotiated with California and involves developing new on-site treatment options as well as finding off-site alternatives.

3.1.3 Environmental Restoration Department

ERD evaluates and remediates soil and groundwater contaminated by past hazardous materials handling and disposal practices and from leaks and spills that have occurred at the Livermore site and Site 300 prior to and during LLNL operations. ERD conducts field investigations at both sites to characterize the existence, extent, and impact of contamination. ERD evaluates and develops various remediation technologies, makes recommendations, and implements actions for site restoration. ERD is responsible for managing remedial activities, such as soil removal and groundwater and soil vapor extraction and treatment, and for decontamination, decommissioning, and demolition of closed facilities in a manner that prevents environmental contamination and completes the facility life cycle. As part of its responsibility for CERCLA compliance issues, ERD plans, directs, and conducts assessments to determine both the impact of past releases on the environment and the restoration activities needed to reduce contaminant concentrations to protect human health and the environment.

3.1.4 Response to Spills and Other Environmental Emergencies

LLNL has an active spill response program to investigate and evaluate all spills and leaks (releases) at LLNL that are potentially hazardous to the environment. During working hours incidents can be reported to the EPD environmental analysts supporting program areas, or the LLNL Fire Dispatch for investigation and response. Off-hour incidents are reported to Fire Dispatch who notifies the Environmental Duty Officer (EDO) and the on-site Fire Department if required. The EDO, who is available 24 hours a day, seven days a week, maximizes efficient and effective emergency environmental response. The EDO and environmental analysts also notify and consult with LLNL management and have seven-day-a-week, 24-hour-a-day access to the Office of Laboratory Counsel for questions concerning regulatory reporting requirements.

3.2 Environmental Management System

LLNL established its EMS to meet the requirements of International Organization for Standardization (ISO) 14001:1996 in June 2004. In 2006, LLNL upgraded its EMS to meet the requirements of ISO 14001:2004, and developed a number of Environmental Management Plans (EMPs) that address lab-wide significant aspects. During FY07 these EMPs were under review to be updated, completed, or eliminated as part of the ongoing EMS process, and to better reflect Executive Order 13423 goals. In late 2006, the EMS was extended to the directorate level.

3.2.1 Multi-Directorate Consortium

In 2007, a Multi-Directorate Consortium (MDC) was formed, consisting of directorate EMS representatives and the members of the P2 Team. The purpose of the MDC was to provide a forum for sharing ideas and identifying common environmental issues that can be worked as a group.

The P2 Team presented MDC sessions on office paper use and reduction, shared chemical usage, and energy topics during 2007. An EMP for office paper usage reduction and recycling was developed by the MDC and adopted by four of the directorates.

3.2.2 Environmental Management Plans

EMS representatives from each program area were tasked with identifying directorate-specific significant aspects and developing directorate EMPs and associated objectives and targets. The review of directorate aspects resulted in significant aspects consistent with those identified previously as having lab-wide significance. Directorates selected aspects to pursue based on which ones they could reasonably affect, based on budget and mission. During 2007, six directorates completed one or more directorate EMP (see **Table 3-1**).

A number of EMPs were developed to address Lab-wide environmental aspects during 2006 and are still in progress, or contain an ongoing component (see **Table 3-2**).

Table 3-1. LLNL Directorate Environmental Management Plans

Directorate	Aspects addressed	Environmental Management Plan(s)
AHR	• Municipal waste generation • Nonhazardous materials use	• Office Paper Use Reduction and Recycling
COMP	• Nonhazardous materials use	• Establish a Cardboard and Pallet Recycling Program
PAT	• Nonhazardous materials use	• Minimizing Outdoor Equipment Storage
	• Hazardous materials use	• Preventing the Formation of Lead Oxide by Sealing Lead Shielding
	• Radioactive materials use	• Minimizing Radioactive Sealed Sources and Reducing Exposure Hazards
NHI	• Municipal waste generation • Nonhazardous materials use	• Office Paper Use Reduction and Recycling
DO	• Municipal waste generation • Nonhazardous materials use	• Office Paper Use Reduction and Recycling
SEP	• All Environmental Aspects	• EMS Employee Awareness and Involvement
	• Municipal waste generation • Nonhazardous materials use	• Office Paper Use Reduction and Recycling
	• Waste reduction	• Pharmaceutical Inventory Reduction Review
	• Mixed waste generation	• Development of Authorized Limits for ERD GAC Filters
	• Hazardous air pollutants emissions • Hazardous waste generation • Industrial waste generation • Hazardous materials use	• Modified Procedure for the Analysis of Plutonium in Urine Samples

Table 3-2. LLNL Environmental Management Plans for Lab-wide aspects

Significant environmental aspect	Objective summary	Status
Ecological resource disturbance	• Establish an LLNL policy prohibiting the introduction of exotic species • Educate LLNL employees about the consequences of exotic species introduction • Control exotic species, e.g., feral pig, largemouth bass	Ongoing.
Electrical energy use	• Meet the objectives provided in DOE Order 430.2A, Departmental Energy and Utilities Management • Implement President's Initiative for Hurricane Relief (September 2005)	Under revision to incorporate Executive Order 13423.
Fossil fuel consumption/ renewable energy use	• Meet the DOE Vehicle Fleet Efficiency goal, in I.106 DEAR 970.5223-5	An E85 fuel station started operation in May 2007. LLNL has 290 E85 compatible alternative fuel vehicles (AFV) on-site and continues to replace conventional fuel vehicles with AFVs per the General Services Administration (GSA) replacement schedule.
Hazardous materials use	• Prioritize hazardous materials used and perform Pollution Prevention Opportunity Assessment to evaluate potential for reduction or substitution	Under revision.
Mixed waste generation	• Reduce the amount of mixed and California combined solid waste generated from routine LLNL programmatic operations when economically and technologically feasible	Evaluation report prepared and EMP updated.
Municipal waste generation	• Maintain compliance with applicable regulatory requirements • Prevent/reduce waste generation and increase reuse/recycling of routine and nonroutine waste that would otherwise be disposed of at a municipal landfill	Under revision.
Nonhazardous materials use	• Incorporate affirmative procurement site-wide • Increase site-wide use of products with recycled content	Procedure revisions completed February 2007. Remaining training sessions scheduled for Q2 FY08.
Radioactive material use	• Conduct study to evaluate radioactive material impacts at LLNL and identify potential opportunities for reduction	Completed.
Transuranic waste generation	• Conduct a study to review the characterization of transuranic waste to ensure generation of nonconforming waste is minimized and characterization is accurate to maximize the ability to disposition the waste.	Completed.

3.2.3 Senior Management Review of EMS

ISO 14001:2004 requires senior management reviews of the EMS at least annually. A management review was held in July 2007 based on input prepared by the EMS Coordinator. The following topics were discussed:

- Results of the 2007 HS-64 Independent Oversight inspection
- Review of organizational environmental performance
- Review of existing EMPs and progress toward objectives and targets
- Changing circumstances, new legal or other requirements
- Status of corrective and preventative actions
- EMS improvements implemented since last management review
- Recommendations for improvement

3.3 Pollution Prevention Program

The LLNL P2 Team facilitates LLNL's P2 Program within the framework of the Integrated Safety Management System (ISMS) and EMS and in accordance with applicable laws, regulations, and DOE orders as required by contract. P2 Team responsibilities include P2 Program stewardship and maintenance, waste stream analysis, reporting of waste generation and P2 accomplishments, and fostering of P2 awareness through presentations, articles, and events. The P2 Team supports institutional and directorate P2 activities via environmental teams, including implementation and facilitation of source reduction and/or reclamation, recycling, and reuse programs for hazardous and nonhazardous waste; facilitation of environmentally preferable procurement; preparation of P2 opportunity assessments; and development and management of high return-on-investment (ROI) projects. LLNL's P2 Program is described in the *ES&H Manual,* Document 30.1.

The P2 Program at LLNL strives to systematically reduce solid, hazardous, radioactive, and mixed waste generation, and to eliminate or minimize pollutant releases to all environmental media from all aspects of the operations at the Livermore site and Site 300. These efforts help protect public health and the environment by reducing or eliminating waste, improving resource usage, and reducing inventories and releases of hazardous chemicals. These efforts also benefit LLNL by reducing compliance costs and minimizing the potential for civil and criminal liabilities under environmental laws. In accordance with EPA guidelines and DOE policy, the P2 Program uses a hierarchical approach to waste reduction (i.e., source elimination or reduction, material substitution, reuse and recycling, and treatment and disposal), which is applied, where feasible, to all types of waste. The P2 Team tracks waste generation using RHWM's HazTrack database. By reviewing the information in this database, program managers and P2 Team staff can monitor and analyze waste streams to determine cost-effective improvements to LLNL operations. Performance metrics for P2 will be incorporated into any future environmental performance metrics that are developed.

LLNL continues its efforts to phase-out Class I ozone depleting substances (ODSs). These efforts include recovery and recycling activities, refrigerant and coolant substitutions, preventative maintenance, leak detection programs, and equipment replacement. LLNL uses minimal quantities of ODSs for mission-critical laboratory research, under the "laboratory exemption" provided for in 40 CFR Part 82, Subpart A, Appendix G.

3.3.1 Routine Hazardous and Radioactive Waste

Routine waste listed in **Table 3-3** includes waste from ongoing operations produced by any type of production, analysis, and research and development taking place at LLNL. Residues resulting from the treatment of routine waste are not included to avoid double counting.

Table 3-3. Routine hazardous and radioactive waste at LLNL, FY 2004–2007.

Waste category	FY 2004	FY 2005	FY 2006	FY 2007
Routine hazardous waste generated	141.3 MT	127 MT	153 MT	138 MT
Routine low-level waste generated	151.3 m^3	54 m^3	66 m^3	197 m^3
Routine mixed waste generated	18.8 m^3	16 m^3	18 m^3	30 m^3
Routine TRU / mixed TRU waste generated	1.2 m^3	1 m^3	1 m^3	3.1 m^3

The FY07 increase in routine low-level waste was due to container closure and certification of previously generated table shot debris from Site 300 explosives testing. The FY07 increase in routine mixed waste reflects a change in the types of waste included as routine. Starting in FY07, aqueous debris washing and aqueous evaporator cleanout waste was reported as routine mixed waste.

Transuranic (TRU) and TRU mixed waste increased during FY07 due to packaging and support waste generated in support of the de-inventory project to transfer special nuclear materials off-site, the close out of existing TRU waste inventories, and other programmatic activities.

3.3.2 Diverted Waste

LLNL maintains an active waste diversion program, encouraging recycling and reuse of both routine and nonroutine waste.

3.3.2.1 Routine Waste

Together, the Livermore site and Site 300 generated 4051 MT of routine nonhazardous solid waste in FY 2007. This volume includes diverted waste (e.g., material diverted through recycling and reuse programs) and landfill waste.

Both sites combined diverted a total 2521 MT of routine nonhazardous waste in 2007, which represents a diversion rate of 62%. The diverted routine nonhazardous waste includes waste recycled by RHWM and materials diverted through the surplus sales program. The portion of routine nonhazardous waste sent to landfill was 1530 MT. See **Table 3-4**.

In 2007, LLNL also recycled 130.7 MT of electronics, which were managed as universal waste.

Table 3-4. Routine nonhazardous waste in FY 2007, Livermore site and Site 300 combined.

Destination	Waste description	Amount in FY 2007 (MT)
Diverted	Batteries, small[(a)]	6
	Batteries, lead-acid[(a)]	24
	Beverage containers	3
	Cardboard	65
	Compost	405
	Cooking grease	3
	Engine oils	9
	Fluorescent lights[(a)]	6
	Magazines, newspapers, phone books	29
	Metals	1379
	Paper	250
	Street sweepings	82
	Tires and scrap	13
	Toner cartridges	7
	Wood	240
	TOTAL diverted	**2521**
Landfill	Compacted (landfill)	1530
	TOTAL landfill	**1530**
TOTAL routine nonhazardous waste		**4051**

(a) Batteries and fluorescent lights are managed as universal waste.

3.3.2.2 Nonroutine Waste

Nonroutine nonhazardous solid wastes include excavated soils, wastes and metals from construction, and decontamination and demolition activities. The Livermore site and Site 300 generated a total of 17,461 MT of nonroutine nonhazardous solid waste in 2007.

In FY 2007, the two sites combined diverted 6195 MT of nonroutine nonhazardous solid waste through reuse or recycling, which represents a diversion rate of 35%. Diverted nonroutine nonhazardous solid waste includes soil reused either on site for other projects or as cover soil at Class II landfills, and metals recycled through the metals recycling programs. See **Table 3-5**.

Table 3-5. Nonroutine nonhazardous waste in FY 2007, Livermore site and Site 300 combined.

Destination	Waste description	Amount in FY 2007 (MT)
Diverted	Class II cover (soil reused at landfill)	503
	Asphalt/concrete	5,172
	Nonroutine metals	520
	TOTAL diverted	**6,195**
Landfill	Construction demolition (noncompacted landfill)	8,602
	Class II concrete	2,558
	Industrial (HazTrack[(a)])	64
	Non-friable asbestos	42
	TOTAL landfill	**11,266**
TOTAL nonroutine nonhazardous waste		**17,461**

(a) RHWM Waste Data Management System

3.3.3 Environmentally Preferable Purchasing

LLNL has a comprehensive Environmentally Preferable Purchasing (EPP) program that includes preferential purchasing of recycled content and biobased products.

The EPP program was expanded in 2007 to include a preference for Electronic Product Environmental Assessment Tool (EPEAT) registered products. 98% of all desktop electronics purchases were EPEAT Silver or EPEAT Gold, indicating that the products meet or exceed the Institute of Electrical and Electronics Engineers (IEEE) 1680-2006 environmental performance standard for electronic products.

3.3.4 Pollution Prevention Activities

3.3.4.1 Environmental Stewardship Awards

The P2 Team nominated two LLNL projects in December 2007 that were selected by NNSA/Headquarters to receive 2007 Environmental Stewardship awards.

LLNL's Space Action Team (SAT) received 2007 Environmental Stewardship recognition for their "Assets for Value" process, which gives contractors the opportunity to include the reuse/salvage value of equipment and recyclable materials from a decontamination and demolition area as an offset in their bid. This process, in place since 2002, reduces the cost of the decontamination and decommissioning (D&D) contracts and maximizes reuse and recycling.

SAT D&D activities are critical to the ongoing ability of LLNL to support its mission because for each facility constructed, LLNL must tear down an equivalent amount of legacy facility space.

In 2007, Assets for Value was applied to the demolition and restoration of a large 1950's era laboratory building, reducing the total project cost by 11%, and resulting in reuse or recycling of 89% of the demolition materials. 227 tons of metals and 5976 tons of concrete/asphalt were diverted for reuse or recycling, along with soil, wood, steel and electro-mechanical infrastructure and equipment.

LLNL Fleet Management received 2007 Environmental Stewardship recognition for implementing an E85 alternate fuel station. The E85 Fueling station started operation in May 2007 and dispensed a total of 41,893 gallons of E85 fuel during 2007. LLNL has 290 E85-compatible alternative fuel vehicles (AFVs) onsite, making it the largest AFV fleet in the DOE complex of national laboratories, and possibly the largest E85 fleet in a single location in California. In collaboration with the CARB, the LLNL station will serve as a test bed for E85 operations throughout the state.

3.3.4.2 Pollution Prevention Accomplishments

The P2 Team documented four additional accomplishments, which were submitted to the DOE Pollution Prevention Tracking Database in December 2007.

Payroll saved paper and associated printing and distribution costs by eliminating 8000 printed monthly leave forms. Employees now access leave and other payroll information online. Eliminating paper forms not only reduced the amount of labor, natural resources, and energy used, but also potentially reduces municipal waste associated with discarded forms.

The LLNL Engineering Records Center provides long-term records retention for various types of data, using film archival to meet 100- to 500-year retention requirements. During 2007, they replaced two chemical-based units with two chemical-free thermal units. This eliminated a 2000 pound/year hazardous photochemical waste stream and improved production throughput as well. Both chemical-based units were sent to salvage, rather than landfill, as an additional environmental measure.

The National Ignition Facility (NIF) Optics Processing Facility made process improvements to extend the useful life of a caustic cleaning solution used in an optics cleaning operation. As a result of their efforts, approximately 900 gallons of hazardous waste were eliminated annually. The reduced frequency of solution changes, along with improved sampling and handling equipment, also increased worker safety.

RHWM implemented streamlined lab pack and bulking operations that resulted in a sixfold increase in operational efficiencies over the previous practice. The change also improved worker safety by eliminating a repackaging step, and significantly reduced the volume and number of waste containers shipped.

3.3.4.3 Pollution Prevention Funding Proposals

ROI projects take into consideration the environmental benefits of a project, and its projected savings, initial investment and ongoing operating costs. ROI project proposals are reviewed by the P2 Team and forwarded to the NNSA Livermore Site Office (NNSA/LSO) for possible funding.

During 2007, one ROI project was selected for funding by the NNSA/LSO. The selected project replaces a Freon vapor degreaser used in the Vacuum Processes Lab with a CO_2 Snow Jet and an ultraviolet ozone (UVO) cleaner. The Freon vapor degreaser was used three to four times a week to clean substrates in preparation for coating. Because Freon is an ozone-depleting substance, an alternative cleaning method was sought. The Snow Jet uses a non-abrasive dust particle removal process to pre-clean the substrate, which is then degreased using the UVO cleaning method. This project resulted in the elimination of approximately 35 gallons of Freon each year. In addition, the new Snow Jet/UVO process is less time consuming, resulting in a 75% savings in labor over the Freon degreaser.

3.3.5 Pollution Prevention Employee Training and Awareness Programs

In 2007, LLNL conducted a number of activities to promote employee awareness of pollution prevention. The annual Earth Expo was held April 16–19 to coincide with Earth Day. The 2007 focus was "Caring for the Environment at Work and at Home." Rather than a single day Expo as in years past, in 2007 the P2 Team held a multi-day lunchtime event at both main site cafeterias and a single day lunchtime event at Site 300. An array of on-site organizations presented posters to increase LLNL staff awareness of the environmental functions carried out by EPD, Fleet, and the Energy Management Program. The LLNL EMS was highlighted at the event, and a recycling survey was conducted to assess employee interest in food and beverage container recycling programs.

The P2 Team conducted other awareness activities during the year. The P2 Team participated in the on-site Environment, Health, and Safety Fair in June. Articles on pollution prevention appeared in *Newsline* (the LLNL newspaper) and *NewsOnLine* (the LLNL electronic newsletter). The P2 Team conducted training for purchasing staff on EPA requirements for affirmative procurement.

The P2 Team maintains an internal P2 website for LLNL employees, which was revamped during 2007. The website is a resource for employees regarding pollution prevention, energy efficiency, reuse and recycling of materials, green building, and other environmental topics. Employees can also use the site to suggest P2 ideas, ask questions about P2 planning and implementation, and find out about P2 current events. The P2 Team also operates the Earth Hotline for employees to call with questions, suggestions, or ideas regarding LLNL's pollution prevention and waste diversion endeavors.

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4. Air Monitoring Programs

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Lawrence Livermore National Laboratory performs continuous air sampling to evaluate its compliance with local, state, and federal laws and regulations and to ensure that human health and the environment are protected. Federal environmental air quality laws and U.S. DOE regulations include 40 CFR 61, Subpart H—the NESHAPs section of the Clean Air Act; applicable portions of DOE Order 5400.5; and ANSI standards. The *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (U.S. DOE 1991) provides the guidance for implementing DOE Order 5400.5.

The EPA Region IX has enforcement authority for LLNL compliance with radiological air emission regulations. Enforcement authority for the Clean Air Act regulations pertaining to nonradiological air emissions belongs to two local air districts: the BAAQMD and the SJVAPCD.

4.1 Air Effluent Monitoring

Air effluent monitoring of atmospheric discharge points is in place for compliance with 40 CFR 61, Subpart H and is used to determine the actual radionuclide releases from individual facilities during routine and nonroutine operations and to confirm the operation of facility emission control systems. Subpart H requires continuous monitoring of facility radiological air effluents if the potential off-site (fence-line) dose equivalent is greater than 1 μSv/y (0.1 mrem/y), as calculated using the EPA-mandated air dispersion dose model, CAP88-PC, without credit for emission control devices. The results of monitoring air discharge points provide the actual emission source information for modeling, which is used to ensure that the NESHAPs standard of 100 μSv/y (10 mrem/y) total site effective dose equivalent is not exceeded. See **Chapter 7** for further information on radiological dose assessment.

Currently, the air effluent sampling program measures only radiological emissions. For LLNL operations with nonradiological discharges, LLNL obtains permits from local air districts (i.e., BAAQMD and SJVAPCD) for stationary emission sources, and from the CARB for portable emission sources such as diesel air compressors and generators. Current permits do not require monitoring of air effluent but do require monitoring of equipment usage, material usage, and record keeping during operations. Based on air toxics emissions inventory and risk assessment required by the California Air Toxics “Hot Spots” Information and Assessment Act of 1987, BAAQMD and SJVAPCD have ranked LLNL as a low-risk facility for nonradiological air emissions.

4.1.1 Air Effluent Radiological Monitoring Results and Impact on the Environment

In 2007, LLNL measured releases of radioactivity from air exhausts at six facilities at the Livermore site and at one facility at Site 300. Air monitoring locations at the Livermore site and Site 300 are shown in **Figures 4-1** and **4-2**, respectively.

In 2007, a total of 0.57 TBq (15.4 Ci) of tritium was released from the Tritium Facility. Of this, approximately 0.42 TBq (11.4 Ci) of tritium was released as vapor (HTO/TTO). The remaining tritium released, 0.15 TBq (4.0 Ci), was gaseous tritium (HT/TT). The tritium emissions from the facility for 2007 are the lowest in decades and may be the lowest since the facility began activities.

In 2007, a total of 1.7×10^{-3} TBq (4.6×10^{-2} Ci) of measured tritium was released from the DWTF. Of this, approximately 1.6×10^{-3} TBq (4.4×10^{-2} Ci) of tritium was released as HTO/TTO, and 6.3×10^{-5} TBq (1.7×10^{-3} Ci) was released as HT/TT. The emissions from the DWTF for 2007 are similar to past years.

The Contained Firing Facility (CFF) at Site 300 had measured depleted uranium emissions in 2007. A total of 2.8×10^{-10} TBq (7.7×10^{-9} Ci) of uranium-234, 1.6×10^{-11} TBq (4.2×10^{-10} Ci) of uranium-235, and 1.8×10^{-9} TBq (4.9×10^{-8} Ci) of uranium-238 was released in particulate form. The emissions were a result of planned activities with depleted uranium.

None of the other facilities monitored for radionuclides had reportable emissions in 2007. The data tables in **Appendix A, Section A.1** provide summary results of all air effluent monitored facilities and include upwind locations (control stations) for gross alpha and gross beta background comparison to stack effluent gross alpha and gross beta results.

The dose to the hypothetical, site-wide maximally exposed member of the public caused by the measured air emissions from the Tritium Facility (modeling HT emissions as HTO as required by EPA) was 1.3×10^{-2} μSv/y (1.3×10^{-3} mrem/y); the dose from the DWTF (modeling HT emissions as HTO) was 4.3×10^{-5} μSv/y (4.3×10^{-6} mrem/y); and the dose from the CFF was 1.1×10^{-6} μSv/y (1.1×10^{-7} mrem/y).

All of the reported doses are less than one-tenth of one percent of the annual NESHAPs standard, which is 100 μSv/y (10 mrem/y) total site effective dose equivalent. As shown in **Chapter 7**, the estimated radiological dose caused by measured air emissions from LLNL operations was minimal. See also the *LLNL NESHAPs 2007 Annual Report* (Bertoldo et al. 2008) for a complete description of air effluent monitoring.

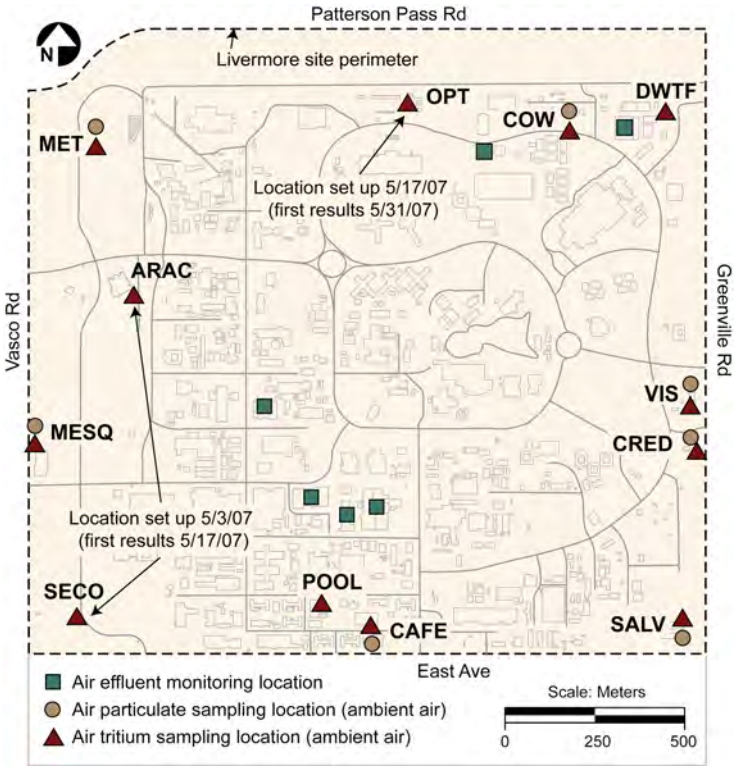

Figure 4-1. Air effluent and ambient air monitoring locations at the Livermore site, 2007.

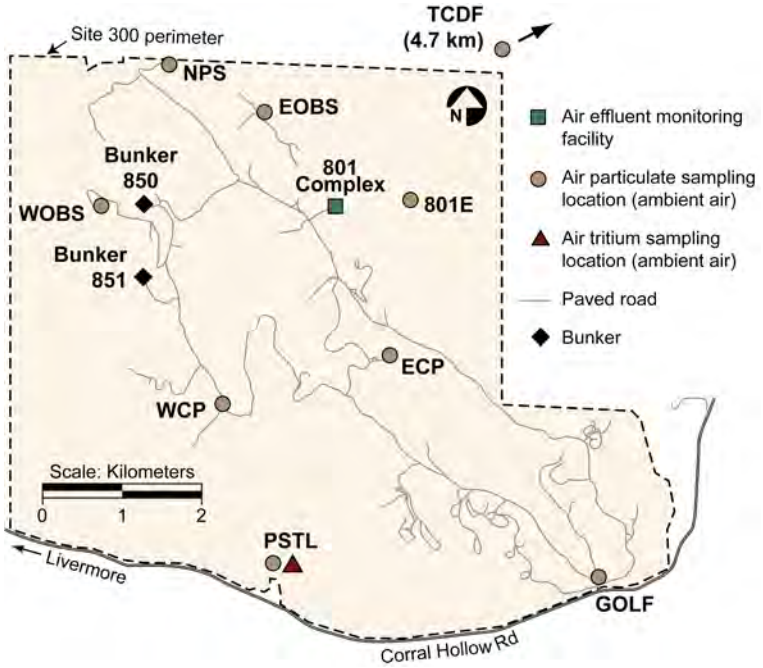

Figure 4-2. Air effluent and ambient air monitoring locations at Site 300, 2007.

4.1.2 Nonradiological Air Releases and Impact on the Environment

In 2007, the Livermore site emitted approximately 143 kg/d of regulated air pollutants as defined by the Clean Air Act, including nitrous oxides (NOx), sulphur oxides (SOx), particulate matter (PM-10), carbon monoxide (CO), and reactive organic gases/precursor organic compounds (ROGs/POCs) (see **Table 4-1**). The stationary emission sources that released the greatest amount of regulated pollutants at the Livermore site were natural gas fired boilers, internal combustion engines (such as diesel generators), solvent cleaning, and surface coating operations (such as painting). Pollutant emission information was primarily derived from monthly material and equipment usage records.

Table 4-1. Nonradioactive air emissions, Livermore site and Site 300, 2007.

	Estimated releases (kg/d)	
Pollutant	**Livermore site**	**Site 300**
ROGs/POCs	17.3	0.48
Nitrogen oxides	65.7	2.32
Carbon monoxide	52.3	0.51
Particulates (PM-10)	6.0	0.39
Sulfur oxides	1.5	0.21
Total	142.8	3.91

Livermore site air pollutant emissions were very low in 2007 compared to the daily releases of air pollutants from all sources in the entire Bay Area. For example, the average daily emission of NOx in the Bay Area was approximately 4.45×10^5 kg/d, compared to the estimated daily release from the Livermore site of 65.7 kg/d, which is 0.015% of total Bay Area source emissions for NOx. The 2007 BAAQMD estimate for ROGs/POCs daily emissions throughout the Bay Area was 3.32×10^5 kg/d, while the daily emission estimate for 2007 from the Livermore site was 17.3 kg/d, or 0.005% of the total Bay Area source emissions for ROGs/POCs.

Certain operations at Site 300 require permits from the SJVAPCD. The estimated daily air pollutant emissions during 2007 from operations (permitted and exempt stationary sources) at Site 300 are listed in **Table 4-1**. The stationary emission sources that release the greatest amounts of regulated air pollutants at Site 300 include internal combustion engines (such as diesel generators), a gasoline-dispensing facility, paint spray booths, and general machine shop operations. Combustion pollutant emissions, such as NOx, CO, SOx, and PM-10, increased at Site 300 in 2007 primarily from the required, periodic preventative maintenance of emergency stand-by diesel generators.

4.2 Ambient Air Monitoring

LLNL conducts ambient air monitoring at on- and off-site locations to determine whether airborne radionuclides or beryllium are being released to the environs in measurable quantities by LLNL operations. Ambient air monitoring also serves to verify the air concentrations predicted by air dispersion modeling and to determine compliance with NESHAPs regulations.

The derived concentration guides (DCGs) in DOE Order 5400.5 specify the concentrations of radionuclides that can be inhaled continuously 365 days a year without exceeding the DOE primary radiation protection standard for the public, which is 1 mSv/y (100 mrem/y) effective dose equivalent.

Beryllium is the only nonradiological emission from LLNL that is monitored in ambient air. LLNL requested and was granted a waiver by the BAAQMD for source-specific monitoring and record keeping for beryllium operations, provided that LLNL can demonstrate that monthly average beryllium concentrations in air are well below regulatory limits of 10,000 pg/m^3. LLNL meets this requirement by sampling for beryllium at perimeter locations.

Based on dispersion modeling using site-specific meteorological data, the ambient air samplers, particularly those on the site perimeters, have been placed to monitor locations where elevated air concentrations due to LLNL operations may occur. Sampling locations for each monitoring network are shown in **Figures 4-1**, **4-2**, and **4-3**.

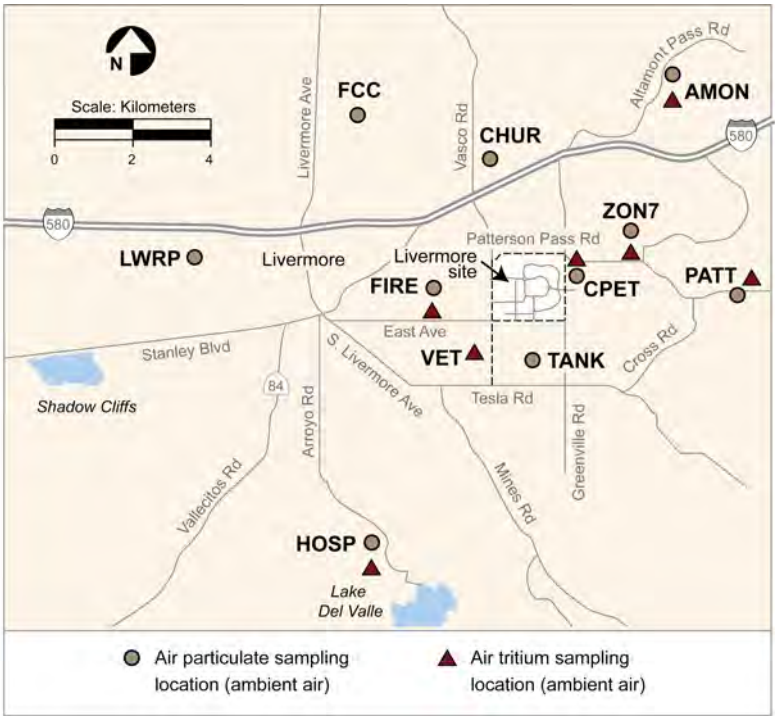

Figure 4-3. Air particulate and tritium monitoring locations in the Livermore Valley, 2007.

4.2.1 Ambient Air Radioactive Particulates

By analyzing air samples for gamma-emitting radionuclides, LLNL verifies that there is no evidence of release of the small inventories of mixed-fission products and radiochemical tracers used by LLNL. Composite samples for the Livermore site and Site 300 were analyzed for an environmental suite of gamma-emitting radionuclide concentrations in air that include fission products, activation products, actinides, and naturally occurring products. The isotopes detected at both sites in 2007 were beryllium-7 (cosmogenic), lead-210, and potassium-40, all of which are naturally occurring in the environment.

Plutonium-239+240 was detected in 8 out of 216 samples taken in 2007. The highest values and percentage of the DCG were as follows:

- Livermore site perimeter: 15 nBq/m^3 (0.41 aCi/m^3); 0.002% of the DCG
- Livermore off-site locations: 28 nBq/m^3 (0.76 aCi/m^3); 0.0038% of the DCG
- Site 300 composite: 6.8 nBq/m^3 (0.18 aCi/m^3); 0.00092% of the DCG

The plutonium-239+240 detection at Site 300 is calculated to be from resuspended fallout from historic aboveground nuclear testing. Site 300 does not use or store plutonium on-site.

Uranium-235 and uranium-238 were detected at all sample locations. Uranium ratios are used to determine the type of uranium present in the environment. Natural uranium has a mathematical uranium-235/uranium-238 ratio of 0.00725, and depleted uranium has a uranium-235/uranium-238 ratio of 0.002. Uranium isotopes are naturally occurring. The annual median uranium-235/ uranium-238 isotopic ratios for 2007 were as follows:

- Livermore site perimeter composite: 0.00737
- Site 300 perimeter: 0.00724
- Site 300 off-site location: 0.00734

The annual uranium-235/uranium-238 isotopic ratio medians are consistent with naturally occurring uranium. All of the individual uranium-235 and uranium-238 results were less than one-tenth of one percent of the DCG as shown in **Appendix A**, **Section A.2**.

Gross alpha and gross beta were sampled for at all locations. The primary sources of alpha and beta activities are naturally occurring radioisotopes. Routine isotopic gamma results indicate the activities are the result of naturally occurring isotopes (uranium, thorium, potassium, and lead), which are also routinely found in local soils. See **Appendix A, Section A.2**.

4.2.2 Ambient Air Tritium Concentrations

The biweekly air tritium data that are provided in **Appendix A**, **Section A.2** are summarized in **Table 4.2**. In 2007, as expected, the highest concentrations of tritium were found near area (diffuse) sources near the Tritium Facility and in the Building 612 yard on the Livermore site. Area sources include stored containers of tritium waste or tritium-contaminated equipment from which HTO diffuses into the atmosphere. These diffuse-source sampling locations were

discontinued mid-year. Air concentrations measured at sampler locations near the Livermore site perimeter were the next highest after those near diffuse sources; the concentrations near the perimeter were, on average, less than 5% of those near the diffuse sources. Location POOL exhibited the highest biweekly concentration of the perimeter locations. With the exception of the downwind sampling location CPET, all of the median concentrations in the Livermore Valley were below the minimum detectable concentration (MDC) in 2007. Given the low tritium concentrations observed at the Livermore site sample locations, remote sample concentrations are readily observed to be below the MDC. Similarly, because no operations at Site 300 released tritium to the environment in 2007, the 6 of 26 sample concentrations measured above the MDC at PSTL is likely an artifact of scintillation counting with a high counter background.

Table 4-2. Air tritium sampling summary for 2007.

Sampling locations	Detection frequency	Concentration (mBq/m^3)				Median % DCG[(a)]	Dose (nSv)
		Mean	Median	IQR	Maximum		
Diffuse on-site sources	18 of 18	730	700	310	1200	0.019%	154
Livermore site perimeter[(b)]	175 of 231	36.1	26.9	30.3	212	0.00073%	7.61
Livermore Valley	80 of 179	17.8	13	19.7	218	0.00035%	3.75
Site 300	6 of 26	5.67	6.46	13.4	23.2	0.00017%	1.19

(a) DCG = derived concentration guide of 3.7×10^6 mBq/m^3 for tritium in air.

(b) Locations COW, DWTF, MET, and POOL are considered near perimeter locations.

For a location at which the mean concentration is at or below the MDC, inhalation dose from tritium is assumed to be less than 5 nSv/y (0.5 µrem/y) (i.e., the annual dose from inhaling air with a concentration at the MDC of about 25 mBq/m^3 [0.675 pCi/m^3]).

4.2.3 Ambient Air Beryllium Concentrations

LLNL measures the monthly concentrations of airborne beryllium at the Livermore site, Site 300, and at the off-site sampler northeast of Site 300. The highest value at the Livermore site in 2007 for airborne beryllium was 16 pg/m^3. This value is only 0.16% of the BAAQMD ambient concentration limit for beryllium (10,000 pg/m^3). These data are similar to data collected from previous years.

There is no regulatory requirement to monitor beryllium in San Joaquin County; however, LLNL analyzes samples from three Site 300 perimeter locations as a best management practice. The monthly median beryllium concentration for these locations was 6.5 pg/m^3. The monthly median concentration for the off-site location was 11 pg/m^3. See **Appendix A, Section A.2**.

4.2.4 Impact of Ambient Air Releases on the Environment

LLNL operations involving radioactive materials had minimal impact on ambient air during 2007. The measured radionuclide particulate and tritium concentrations in air at the Livermore site and

Site 300 were all less than one-tenth of one percent of the DCG. These levels do not indicate the presence of a threat to the environment or public health.

Beryllium is naturally occurring and has a soil concentration of approximately 1 part per million. The sampled results are believed to be from naturally occurring beryllium that was resuspended from the soil and collected by the sampler. Even if the concentrations of beryllium detected were from LLNL activities, the amount is still less than one percent of the BAAQMD ambient air concentration limit, and as such, does not present a concern for public safety or the environment.

5. Water Monitoring Programs

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Lawrence Livermore National Laboratory monitors a multifaceted system of waters that includes wastewaters, storm water, and groundwater, as well as rainfall and local surface waters. Water systems at the two LLNL sites (the Livermore site and Site 300) operate differently. For example, the Livermore site is serviced by publicly owned treatment works but Site 300 is not, resulting in different methods of treating and disposing of sanitary wastewater at the two sites. Many drivers determine the appropriate methods and locations of the various water monitoring programs, as described below.

In general, water samples are collected according to written, standardized procedures appropriate for the medium (Woods 2005). Sampling plans are prepared by the LLNL network analysts who are responsible for developing and implementing monitoring programs or networks. Network analysts decide which analytes are sampled (see **Appendix B**) and at what frequency, incorporating any permit-specified analyses. Except for analyses of certain sanitary sewer and retention tank analytes, analyses are usually performed by off-site, California-certified contract analytical laboratories.

5.1 Sanitary Sewer Effluent Monitoring

In 2007, the Livermore site discharged an average of 1.11 million L/d (292,308 gal/d) of wastewater to the City of Livermore sewer system, or 4% of the total flow into the City's system. This volume includes wastewater generated by Sandia/California and a very small quantity from Site 300. In 2007, Sandia/California generated approximately 10% of the total effluent discharged from the Livermore outfall. Wastewater from Sandia/California and Site 300 is discharged to the LLNL collection system and combined with LLNL sewage before it is released at a single point to the municipal collection system.

LLNL's wastewater contains both sanitary sewage and process wastewater and is discharged in accordance with permit requirements and the City of Livermore Municipal Code, as discussed below. Most of the process wastewater generated at the Livermore site is collected in various retention tanks and discharged to LLNL's collection system under prior approval from LLNL's Water Guidance and Monitoring Division (WGMD) Waste Discharge Authorization Requirement (WDAR) approval process.

5.1.1 Livermore Site Sanitary Sewer Monitoring Complex

LLNL's sanitary sewer discharge permit (Permit 1250, 2006/2007 and 2007/2008) requires continuous monitoring of the effluent flow rate and pH. Samplers at the Sewer Monitoring

Station (SMS) collect flow-proportional composite samples and instantaneous grab samples that are analyzed for metals, radioactivity, total toxic organics, and other water-quality parameters.

5.1.1.1 Radiological Monitoring Results

DOE orders and federal regulations establish the standards of operation at LLNL (see **Chapter 2**), including the standards for sanitary sewer discharges. Primarily the standards for radioactive material releases are contained in complementary (rather than overlapping) sections of the DOE Order 5400.5 and 10 CFR Part 20.

For sanitary sewer discharges, DOE Order 5400.5 provides the criteria DOE has established for the application of best available technology to protect public health and minimize degradation of the environment. These criteria (the DCGs) limit the concentration of each radionuclide discharged to publicly owned treatment works. If the measured monthly average concentration of a radioisotope exceeds its concentration limit, LLNL is required to improve discharge control measures until concentrations are again below the DOE limits.

The 10 CFR Part 20 sanitary sewer discharge numerical limits include the following annual discharge limits for radioactivity: tritium, 185 GBq (5 Ci); carbon-14, 37 GBq (1 Ci); and all other radionuclides combined, 37 GBq (1 Ci). The 10 CFR Part 20 limit on total tritium activity dischargeable during a single year (185 GBq [5 Ci]) takes precedence over the DOE Order 5400.5 concentration-based limit for tritium for facilities that generate wastewater in large volumes, such as LLNL. In addition to complying with the 10 CFR Part 20 annual mass-based discharge limit for tritium and the DOE monthly concentration-based discharge limit for tritium, LLNL also complies with the daily effluent concentration-based discharge limit for tritium established by WRD for LLNL. The WRD limit is smaller by a factor of 30 than the DOE monthly limit so the limits are therefore essentially equivalent; however, the WRD limit is more stringent in the sense that it is daily rather than monthly. The radioisotopes with the potential to be found in sanitary sewer effluent at LLNL and their discharge limits are discussed below. All analytical results are provided in **Appendix A**, **Section A.3**.

LLNL determines the total radioactivity contributed by tritium, gross alpha emitters, and gross beta emitters from the measured radioactivity in the monthly effluent samples. As shown in **Table 5-1**, the 2007 combined release of alpha and beta sources was 0.22 GBq (0.006 Ci), which is 0.6% of the corresponding 10 CFR Part 20 limit (37 GBq [1.0 Ci]). The tritium total was 2.83 GBq (0.08 Ci), which is 1.5% of the 10 CFR Part 20 limit (185 GBq [5 Ci]).

Table 5-1. Estimated total radioactivity in LLNL sanitary sewer effluent, 2007.

Radioactivity	Estimate based on effluent activity (GBq)	Limit of sensitivity (GBq)
Tritium	2.83	0.95
Gross alpha	0.01	0.05
Gross beta	0.21	0.11

Discharge limits and a summary of the measurements of tritium in the sanitary sewer effluent from LLNL and WRD are reported in LLNL monthly reports. The maximum daily concentration for tritium of 0.58 Bq/mL (16 pCi/mL) was far below the permit discharge limit of 12 Bq/mL (333 pCi/mL).

Measured concentrations of cesium-137 and plutonium-239 in the sanitary sewer effluent from LLNL, WRD, and in WRD sludge are reported in the LLNL March 2008 Report (Revelli 2008a). Cesium and plutonium results are from monthly composite samples of LLNL and WRD effluent and from quarterly composites of WRD sludge. For 2007, the annual total discharges of cesium-137 and plutonium-239 were far below the DOE DCGs. Plutonium discharged in LLNL effluent is ultimately concentrated in WRD sludge. The highest plutonium concentration observed in 2007 sludge is 0.19 mBq/g (0.005 pCi/g), which is many times lower than the U.S. EPA preliminary remediation goal for residential soil (93 mBq/dry g [2.5 pCi/dry g]) and is 0.05% of the remediation goal for industrial or commercial soil (370 mBq/dry g [10 pCi/dry g]).

The historical levels for plutonium-239 observed since 1997 averaged approximately 1 μBq/mL (3×10^{-5} pCi/mL). The historical levels are generally 0.0003% of the DOE DCG for plutonium−239. The highest plutonium and cesium concentrations are well below DOE DCGs.

LLNL also compares annual discharges with historical values to evaluate the effectiveness of ongoing discharge control programs. **Table 5-2** summarizes the radioactivity in sanitary sewer effluent over the past 10 years. During 2007, a total of 2.83 GBq (0.08 Ci) of tritium was discharged to the sanitary sewer, an amount that is well within environmental protection standards and is comparable to the amounts discharged during the past 20 years.

Table 5-2. Historical radioactive liquid effluent releases from the Livermore site, 1997–2007.[(a)]

Year	Tritium (GBq)	Plutonium-239 (GBq)
1997	9.1	2.1×10^{-4}
1998	10	0.77×10^{-4}
1999	7.1	0.68×10^{-4}
2000	5.0	0.96×10^{-4}
2001	4.9	1.1×10^{-4}
2002	0.74	0.42×1^{-4}
2003	1.11	0.51×10^{-4}
2004	1.34	1.16×10^{-5}
2005	3.12	9.64×10^{-6}
2006	19.9	7.56×10^{-6}
2007	2.83	6.24×10^{-6}

(a) Starting in 2002, following DOE guidance, actual analytical values instead of LOS values were used to calculate total.

5.1.1.2 Nonradiological Monitoring Results

LLNL monitors sanitary sewer effluent for chemical and physical parameters at different frequencies depending on the intended use of the result. For example, LLNL's wastewater discharge permit requires LLNL to collect monthly grab samples and 24-hour composites, weekly composites, and daily composites. Once a month, a 24-hour, flow-proportional composite is collected and analyzed; this is referred to as the monthly 24-hour composite in the discussion below. The weekly composite refers to the flow-proportional samples collected over a 7-day period continuously throughout the year. The daily composite refers to the flow-proportional sample collected over a 24-hour period, also collected continuously throughout the year. LLNL's wastewater discharge permit specifies that the effluent pollutant limit (EPL) is equal to the maximum pollutant concentration allowed per 24-hour composite sample. Only when a weekly composite sample concentration is at or above 50% of its EPL are the daily samples that were collected during the corresponding period analyzed to determine whether any of the concentrations are above the EPL.

A summary of the analytical results from the permit-specified monthly and weekly composite sampling programs is presented in **Table 5-3**. The permit also requires that grab samples of effluent be collected on a monthly and semiannual basis, and analyzed for total toxic organic compounds (TTO) and cyanide, respectively. (Complete results from LLNL's 2007 sanitary sewer effluent monitoring program are provided in **Appendix A**, **Section A.3**.)

During 2007, concentrations of the regulated metals show generally good agreement between the monthly composite samples and the corresponding weekly composite samples, and these results closely resemble the 2006 results. In **Table 5-3**, the 2007 maximum concentration for each metal is shown and compared with the EPL. These maximum values did not exceed 10% of their respective EPLs for eight of the nine regulated metals. Only arsenic, with maximum values of 14% and 17% of its EPL (monthly and weekly composite concentrations, respectively), was reported to have a maximum concentration above 10% of its EPL; comparable to 2006 results. All of the monthly 24-hour composite and weekly composite samples were in compliance with LLNL's wastewater discharge permit limits.

Figure 5-1 presents historical trends for the monthly 24-hour composite sample results from 2000 through 2007 for eight of the nine regulated metals; cadmium is not presented because this metal was not detected above the practical quantitation limit (PQL) in any of the 2000 through 2007 monthly sampling events. (Typical PQLs for the regulated metals in LLNL sanitary effluent are shown in **Table 5-3**.) The 2007 results routinely show concentrations of arsenic, copper, lead, and zinc at levels above their respective PQLs; nickel was detected in 5 of 12 samples, while silver, chromium, and mercury showed only one detection above their respective PQLs. These observations are generally consistent with the 2000 through 2004 data; however, with the exception of arsenic, the concentrations of those metals detected in 2005 through 2007 have shown an overall downward trend. The range of monthly 24-hour composite concentrations reported for arsenic in 2007, although never exceeding 14% of its EPL, has not shown a similar downward trend.

Table 5-3. Summary of analytical results for permit-specified composite sampling of the LLNL sanitary sewer effluent, 2007.

Sample	Parameter	Detection frequency[a]	PQL[b]	EPL[c]	Minimum	Maximum	Median	Maximum % of EPL
Monthly 24-hour Composite	**Oxygen demand (mg/L)**							
	Biochemical oxygen demand	12 of 12	2	None Specified	69	170	96.5	N/A
	Solids (mg/L)							
	Total dissolved solids	12 of 12	1	None Specified	160	770	240	N/A
	Total suspended solids	12 of 12	1	None Specified	44	110	63	N/A
	Total metals (mg/L)							
	Silver	1 of 12	0.010	0.20	<0.01	0.017	<0.01	8.5
	Arsenic	9 of 12	0.0020	0.06	<0.002	0.0083	0.0063	14
	Cadmium	0 of 12	0.0050	0.14	<0.005	<0.005	<0.005	<3.6
	Chromium	1 of 12	0.010	0.62	<0.01	0.015	<0.01	2.4
	Copper	12 of 12	0.010	1.0	0.038	0.10	0.053	10
	Mercury	1 of 12	0.00020	0.01	<0.0002	0.00029	<0.0002	2.9
	Nickel	5 of 12	0.0050	0.61	<0.005	0.0080	<0.005	1.3
	Lead	10 of 12	0.0020	0.20	<0.002	0.0067	0.0028	3.4
	Zinc	12 of 12	0.050	3.00	0.078	0.17	0.12	5.7
Weekly Composite	**Total metals (mg/L)**							
	Silver	1 of 52	0.010	0.20	<0.01	0.011	<0.01	5.5
	Arsenic	41 of 52	0.0020	0.06	<0.002	0.01	0.0031	17
	Cadmium	0 of 52	0.0050	0.14	<0.005	<0.005	<0.005	<3.6
	Chromium	0 of 52	0.010	0.62	<0.01	<0.01	<0.01	<1.6
	Copper	52 of 52	0.010	1.0	0.019	0.079	0.035	7.9
	Mercury	1 of 52	0.00020	0.01	<0.0002	0.00024	<0.0002	2.4
	Nickel	2 of 52	0.0050	0.61	<0.005	0.0056	<0.005	0.92
	Lead	17 of 52	0.0020	0.20	<0.002	0.015	<0.002	7.5
	Zinc	47 of 52	0.050	3.00	<0.05	0.16	0.065	5.3

(a) The number of times an analyte was positively identified, followed by the number of samples that were analyzed (generally 12, one sample for each month of the year; or 52, one sample for each week of the year).

(b) PQL = Practical quantitation limit (these limits are typical values for sanitary sewer effluent samples).

(c) EPL = Effluent pollutant limit (LLNL Wastewater Discharge Permit 1250, 2006/2007 and 2007/2008).

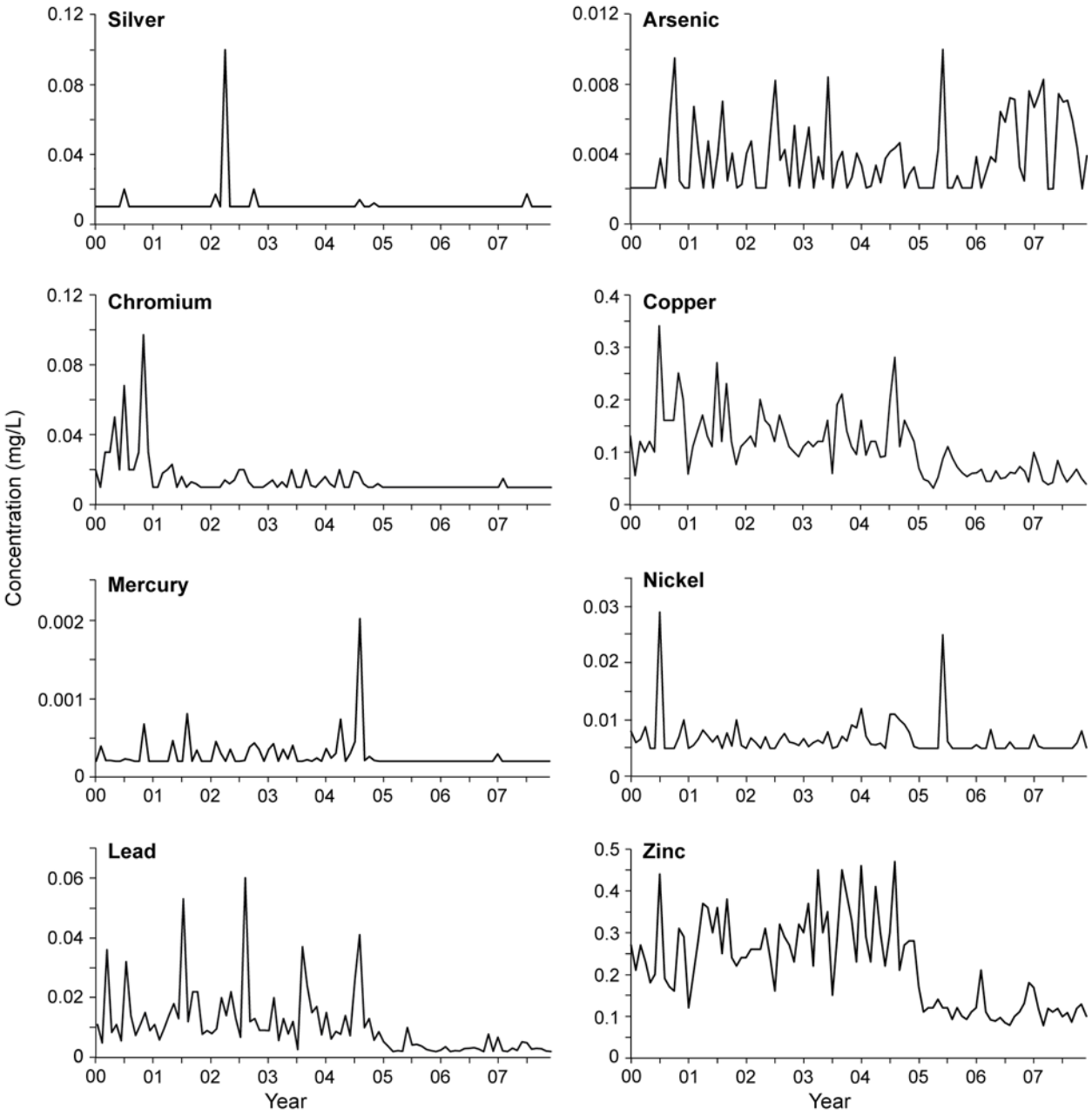

Figure 5-1. Monthly 24-hour composite sample concentrations for eight of the nine regulated metals in LLNL sanitary sewer effluent showing historical trends.

As previously noted, grab samples of LLNL's sanitary sewer effluent are collected monthly for TTO analysis (permit limit = 1.0 mg/L) and semiannually for cyanide analysis (permit limit = 0.04 mg/L). In 2007, LLNL did not exceed either of these discharge limits. Results from the monthly TTO analyses for 2007 show that no priority pollutants, listed by the EPA as toxic organics, were identified in LLNL effluent above the 10 µg/L permit-specified reporting limit. As shown in **Appendix A**, **Section A.3**, three non-regulated organic compounds (acetone, acetonitrile, and ethanol) were identified in monthly grab samples at concentrations above the

10 μg/L permit-specified reporting limit. Cyanide was below the analytical detection limit (0.02 mg/L) in both the April and November samples.

5.1.2 Categorical Processes

The EPA has established pretreatment standards for categories of industrial processes that EPA has determined are major contributors to point-source water pollution. These federal standards include prescribed sampling, self-monitoring, reporting, and numerical limits for the discharge of category-specific pollutants. At LLNL, the categorical pretreatment standards are incorporated into the wastewater discharge permit (Permit 1250, 2006/2007 and 2007/2008), which is administered by the WRD.

The processes at LLNL that are defined as categorical change as programmatic requirements dictate. During 2007, the WRD identified 14 wastewater-generating processes at LLNL that are defined under either 40 CFR Part 469 or 40 CFR Part 433.

Only processes that discharge to the sanitary sewer require semiannual sampling, inspection, and reporting. Two of the 14 processes discharge wastewater to the sanitary sewer: semiconductor processes located in the Building 153 microfabrication facility, and the abrasive jet machining located in Building 321C. In 2007, LLNL analyzed compliance samples for all regulated parameters from both processes and demonstrated compliance with all federal categorical discharge limits. As a further environmental safeguard, LLNL sampled the wastewater in each tank prior to each discharge to the sanitary sewer. These monitoring data were reported to the WRD in July 2007 and January 2008 semiannual wastewater reports (Grayson et al. 2007, 2008).

The remaining 12 processes, which do not discharge wastewater to the sanitary sewer, are regulated under 40 CFR Part 433. Wastewater from these processes is either recycled or contained for eventual removal and appropriate disposal by RHWM. Because the processes do not discharge directly or indirectly to the sanitary sewer, they are not subject to the monitoring and reporting requirements contained in the applicable standard. (See Grayson et al. 2007, 2008).

As required in LLNL's wastewater discharge permit, LLNL demonstrated compliance with permit requirements by semiannual sampling and reporting in 2007. In addition, WRD source control staff performed their required annual inspection and sampling of the two discharging categorical processes in October 2007. The compliance samples were analyzed for all regulated parameters, and the results demonstrated compliance with all federal and local pretreatment limits.

5.1.3 Discharges of Treated Groundwater

LLNL's groundwater discharge permit (1510G, 2006–2008) allows treated groundwater from the Livermore site GWP to be discharged in the City of Livermore sanitary sewer system (see **Chapter 8** for more information on the GWP). During 2007, a total of 69.4 million L (18.3 million gal) of treated groundwater were discharged to the sanitary sewer. This entire volume was associated with GWP treatment operations at well W-404. LLNL did not discharge groundwater from any other location to the sanitary sewer during 2007. All discharges were in

compliance with self-monitoring permit provisions and discharge limits of the permit. Complete monitoring data are presented in Revelli (2008a).

5.1.4 Environmental Impact of Sanitary Sewer Effluent

During 2007, no discharges exceeded any discharge limits for either radioactive or nonradioactive materials to the sanitary sewer. The data are comparable to the lowest historical LLNL values. All the values reported for radiological releases are a fraction of their corresponding limits. For nonradiological releases, LLNL achieved excellent compliance with all the provisions of its wastewater discharge permit.

The data demonstrate that LLNL continues to have excellent control of both radiological and nonradiological discharges to the sanitary sewer. Monitoring results for 2007 reflect an effective year for LLNL's award winning wastewater discharge control program(1) and indicate no adverse impact to the WRD or the environment from LLNL sanitary sewer discharges.

5.2 Site 300 Sewage Ponds

Wastewater samples collected from the influent to the sewage evaporation pond, within the sewage evaporation pond, and flow to the sewage percolation pond were obtained in accordance with the written, standardized procedures summarized in Woods (2005).

5.2.1 Sewage Evaporation and Percolation Ponds

Sewage (nonhazardous wastewater) generated at buildings in the General Services Area at Site 300 is disposed of through a lined evaporation pond. However, during winter rains, treated wastewater may discharge into an unlined percolation pond where it enters the ground and the shallow groundwater.

The environmental monitoring requirements for the sewage evaporation and percolation ponds (hereafter collectively referred to as sewage ponds) are specified in the Monitoring and Reporting Program (MRP) for WDR 96-248. The monitoring requirements include both wastewater monitoring and groundwater monitoring to detect potential impacts of the sewage on groundwater quality.

All wastewater parameters for the sewage evaporation and percolation ponds complied with permit provisions and specifications throughout 2007. All of the monitoring results are reported in the required quarterly monitoring reports (Brown 2007b; Ridley 2007a, 2007b, 2008).

5.2.2 Environmental Impact of Sewage Ponds

All discharges from the Site 300 sewage evaporation pond to the percolation pond were in compliance with discharge limits. Groundwater monitoring related to this area indicated there were no measurable impacts to the groundwater from the sewage pond operations (Ridley 2008).

(1) The wastewater discharge control program received the California Water Environment Association (CWEA) Facility of the Year award in 2007.

5.3 Storm Water Compliance and Surveillance Monitoring

LLNL monitors storm water at the Livermore site in accordance with Permit WDR 95-174 (SFBRWQCB 1995) and at Site 300 in accordance with the California NPDES General Permit for Storm Water Discharges Associated with Industrial Activities (WDR 97-03-DWQ) (SWRCB 1997). Site 300 storm water monitoring also meets the requirements of the *Post-Closure Plan for the Pit 6 Landfill Operable Unit* (Ferry et al. 1998). For construction projects that disturb 1 acre of land or more, LLNL also meets storm water compliance monitoring requirements of the California NPDES General Permit for Storm Water Discharges Associated with Construction Activity (WDR 99-08-DWQ) (SWRCB 1999). Storm water monitoring at both sites also follows the requirements in the *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (U.S. DOE 1991) and meets the applicable requirements of DOE Order 5400.5. **Appendix B** includes the current list of analyses conducted on storm water, including analytical methods and typical reporting limits.

At all monitoring locations grab samples are collected by submerging sample bottles directly into the storm water discharge. If a sample location is not directly accessible, an automatic water sampler is used to pump water into the appropriate containers. LLNL permits require sample collection and analysis at the sample locations specified in the permit two times per rainy season. Influent (upstream) sampling is also required at the Livermore site. In addition, LLNL is required to visually inspect the storm drainage system during one storm event per month in the wet season (defined as October through April for the Livermore site and October through May for Site 300) to observe runoff quality and twice during the dry season to identify any dry weather flows. Annual facility inspections are also required to ensure that the best management practices for controlling storm water pollution are implemented and adequate.

5.3.1 LLNL Site-Specific Storm Water

Various chemical analyses are performed on the storm water samples collected. There are no numeric concentration limits for storm water effluent; moreover, the EPA's benchmark concentration values for storm water are not intended to be interpreted as limits (U.S. EPA 2000). To evaluate the program, LLNL has established site-specific thresholds for selected parameters (Campbell and Mathews 2006). A value exceeds a parameter's threshold when it is greater than the 95% confidence limit for the historical mean value for that parameter (see **Table 5-4**). The thresholds are used to identify out-of-the-ordinary data that merit further investigation to determine whether concentrations of that parameter are increasing in the storm water runoff.

Table 5-4. Site-specific thresholds for selected water quality parameters for storm water runoff.[a]

Parameter	Livermore site	Site 300
Total suspended solids (TSS)	750 mg/L[b]	1,700 mg/L[b]
Chemical oxygen demand (COD)	200 mg/L[b]	200 mg/L[b]
pH	<6.0, >8.5[b]	<6.0, >9.0[c]
Nitrate (as NO_3)	10 mg/L[b]	Not monitored
Orthophosphate	2.5 mg/L[b]	Not monitored
Beryllium	1.6 µg/L[b]	1.6 µg/L[b]
Chromium(VI)	15 µg/L[b]	Not monitored
Copper	36 µg/L[b]	Not monitored
Lead	15 µg/L[d]	30 µg/L[b]
Zinc	350 µg/L[b]	Not monitored
Mercury	above RL[e]	1 µg/L[b]
Diuron	14 µg/L[b]	Not monitored
Oil and grease	9 mg/L[b]	9 mg/L[b]
Tritium	36 Bq/L[b]	3.17 Bq/L[b]
Gross alpha radioactivity	0.34 Bq/L[b]	0.90 Bq/L[b]
Gross beta radioactivity	0.48 Bq/L[b]	1.73 Bq/L[b]

(a) If data exceed the threshold comparison criteria, an investigation is initiated to assess if those data are indicative of a water quality problem.

(b) Site-specific value calculated from historical data and studies. These values are lower than the MCLs and EPA benchmarks except for copper, COD, TSS, and zinc

(c) EPA benchmark

(d) California and EPA drinking water action level

(e) RL (reporting limit) = 0.0002 mg/L for mercury

5.3.2 Storm Water Inspections

Each directorate at LLNL conducts an annual inspection of its facilities to verify implementation of the Storm Water Pollution Prevention Plans (SWPPPs) and to ensure that measures to reduce pollutant discharges to storm water runoff are adequate. LLNL's associate directors certified in 2007 that their facilities complied with the provisions of LLNL's SWPPPs. LLNL submits annual storm water monitoring reports to the SFBRWQCB (Campbell and Brunckhorst 2007) and to the CVRWQCB (Brown 2007a) with the results of sampling, observations, and inspections.

For each construction project permitted by WDR 99-08-DWQ, LLNL conducts visual monitoring of construction sites before, during, and after storms to assess the effectiveness of the best management practices. Annual compliance certifications summarize the inspections.

5.3.3 Livermore Site

The Livermore site storm water runoff monitoring network consists of nine sampling locations (see **Figure 5-2**). LLNL collected samples at all nine locations on February 22 and December 18, 2007. Fish toxicity tests were performed on December 18, 2007, and no toxicity issues were identified.

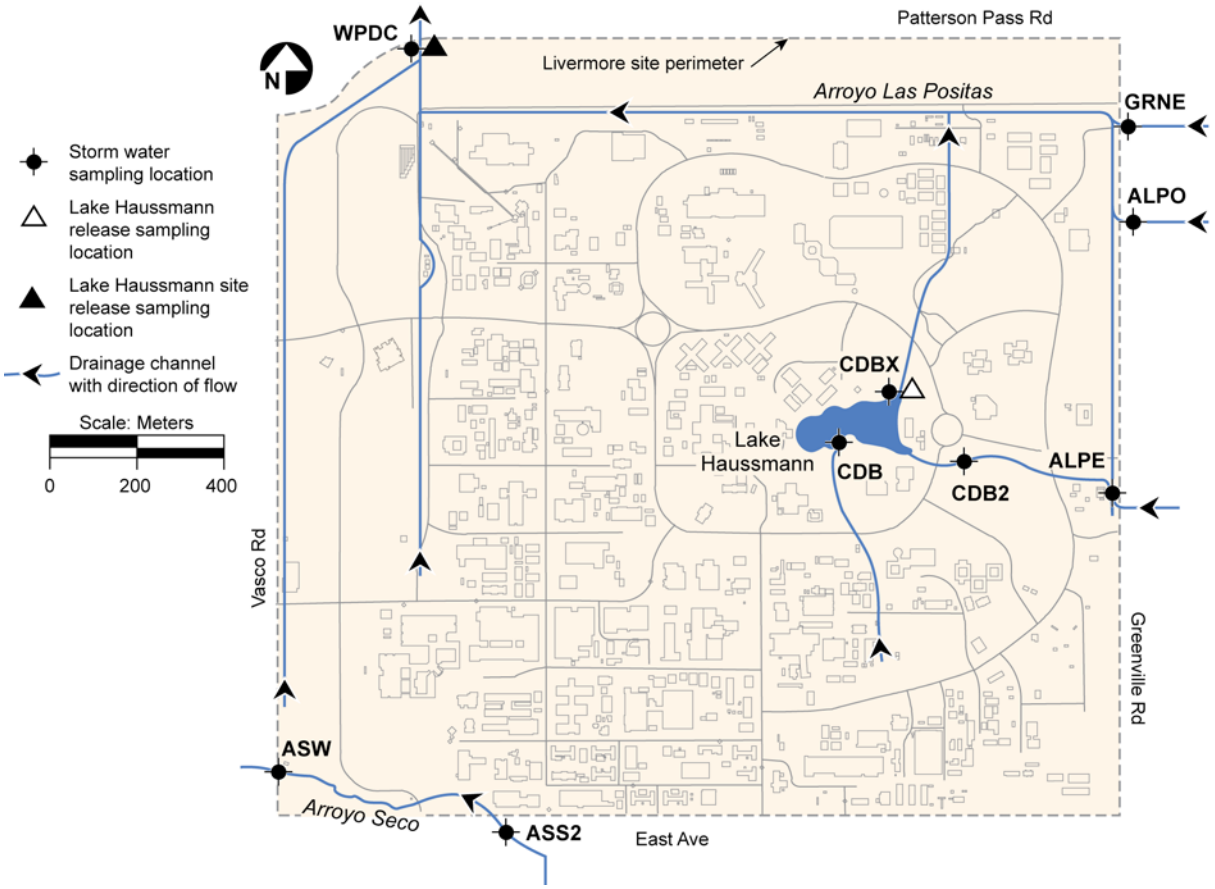

Figure 5-2. Storm water runoff and Lake Haussmann sampling locations, Livermore site, 2007.

5.3.3.1 Radiological Monitoring Results

Storm water gross alpha, gross beta, and tritium results are summarized in **Table 5-5**. (Complete analytical results are provided in **Appendix A**, **Section A.4**.) Tritium activities at the site effluent sampling locations were less than 1% of the maximum contaminant level (MCL). Gross alpha and gross beta radioactivity in the storm water samples collected during 2007 were also generally low, less than 72% and 49% of their MCLs, respectively.

Gross alpha and beta activities exceeded LLNL-specific thresholds on February 22, 2007, in water samples collected at influent location ALPO (see **Table 5-6**). However, gross alpha and beta activities in samples collected from the effluent location WPDC on the same date were well

below the thresholds. Therefore, this result was unlikely to be related to LLNL activities. LLNL began analyzing for plutonium in storm water in 1998. Current storm water sampling locations for plutonium are the Arroyo Seco and the Arroyo Las Positas effluent locations (ASW and WPDC). In 2007, there were no plutonium results above the detection limit of 0.0037 Bq/L (0.10 pCi/L).

Table 5-5. Radioactivity in storm water from the Livermore site, 2007.[a]

Parameter	Tritium (Bq/L)	Gross Alpha (Bq/L)	Gross Beta (Bq/L)
MCL	740	0.555	1.85
Influent			
Minimum	–0.80	–0.009	0.083
Maximum	7.00	0.400	0.900
Median	0.40	0.037	0.120
Effluent			
Minimum	–0.80	0.004	0.078
Maximum	4.30	0.029	0.130
Median	2.50	0.012	0.089

(a) See **Chapter 9** for an explanation of calculating summary statistics.

5.3.3.2 Nonradiological Monitoring Results

Nonradiological results were compared to the site-specific thresholds listed in **Table 5-4**. Of interest were the constituents that exceeded the thresholds at effluent points and whose concentrations were lower in influent than in effluent water samples. If influent concentrations are higher than effluent concentrations, the source is generally assumed to be unrelated to LLNL operations and LLNL conducts no further investigation. (Complete analytical results are provided in **Appendix A**, **Section A.4**.)

Constituents that exceeded site-specific thresholds for effluent and/or influent locations are listed in **Table 5-6**. All of the values above the site-specific thresholds for the Livermore site during 2007 were found at influent tributaries at similar or higher concentrations than at effluent locations. A majority of the data in **Table 5-6** appear to be sediment associated contaminants flowing on-site at location ALPO on February 22. The presence of diuron (an herbicide used for roadside vegetation management) in runoff flowing onto the LLNL site has been documented by Campbell et al. (2004). These results suggest that current operations at the Livermore site during 2007 did not impact the quality of storm water runoff.

Table 5-6. Water quality parameters in storm water runoff above LLNL site-specific thresholds, Livermore site in 2007.

Nonradioactive/ Radioactive	Parameter	Date	Location	Influent / Effluent	Result	LLNL threshold
Nonradioactive	Lead (µg/L)	2/22	ALPO	Influent	32	15
	Diuron (µg/L)	2/22	ALPE	Influent	400	14
		2/22	ALPO	Influent	70	14
		2/22	CDB2	On-site	25	14
		2/22	GRNE	Influent	97	14
		12/18	ALPE	Influent	51	14
		12/18	ALPO	Influent	130	14
		12/18	GRNE	Influent	19	14
		12/18	WPDC	Effluent	23	14
	Nitrate (NO_3) (mg/L)	2/22	GRNE	Influent	22.0	10.0
		12/18	GRNE	Influent	35.0	10.0
		12/18	ALPO	Influent	14.0	10.0
	Total suspended solids (mg/L)	2/22	ALPO	Influent	1300	750
Radioactive	Gross alpha (Bq/L)	2/22	ALPO	Influent	0.4	0.34
	Gross beta (Bq/L)	2/22	ALPO	Influent	0.9	0.48

5.3.4 Site 300

On February 22, 2007, storm water samples were collected and analyzed from all locations that normally have storm water flow. These were three sampling locations (NLIN2, NPT7, and N883) that characterize runoff from on-site industrial activities, an upstream off-site location (CARW2) and a downstream off-site location (GEOCRK) on the Corral Hollow Creek (**Figure 5-3**). No significant runoff was detected at two similar sampling locations (NPT6 and N829).

5.3.4.1 Radiological Monitoring Results

During 2007, none of the radiological analytical results from the storm water samples exceeded the site-specific thresholds listed in **Table 5-4**. (Complete analytical results are provided in **Appendix A**, **Section A.4**.)

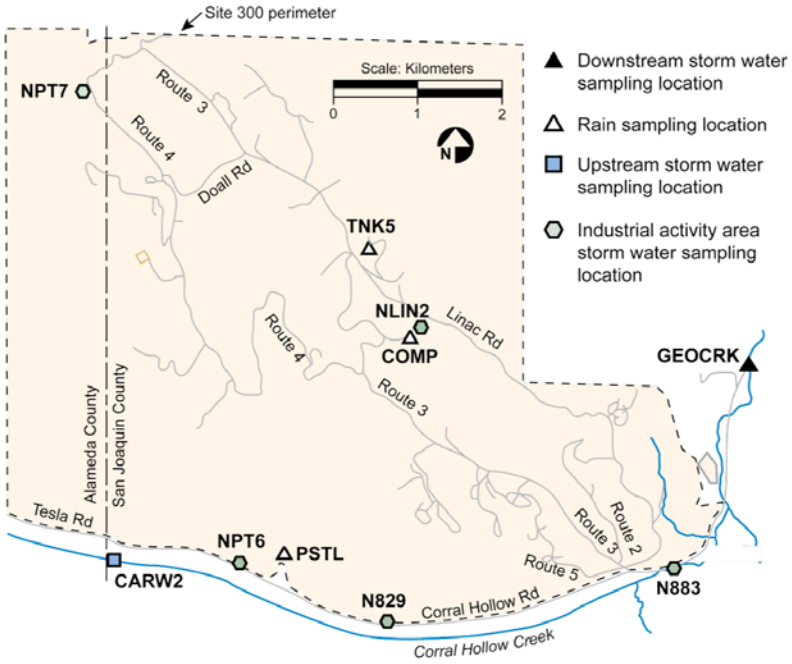

Figure 5-3. Storm water and rainwater sampling locations at Site 300, 2007.

5.3.4.2 Nonradiological Monitoring Results

No nonradiological constituents exceeded the site-specific thresholds listed in **Table 5-4** during 2007. As in the past, low concentrations of dioxins were detected in water samples from storm runoff at Site 300. The federal MCL for dioxin and furans (dioxin-like compounds) is for the most toxic congener 2,3,7,8-tetrachloro-dibenzo-*p*-dioxin (2,3,7,8-tetraCDD). The other dioxin and furan congeners have varying degrees of toxicity. EPA has assigned toxicity equivalency factors (TEFs) to specific dioxin and furan congeners. The congeners 2,3,7,8-tetraCDD and 1,2,3,7,8-pentaCDD have an assigned TEF of 1; the other dioxin and furan congeners have TEFs of <1. The toxicity equivalency (TEQ) is determined by multiplying the concentration of a dioxin and furan congener by its TEF. See **Appendix A**, **Section A.4**, for the concentrations of dioxin and furan compounds that have non-zero TEFs along with their calculated TEQs. Using the approach of multiplying the dioxin and furan congeners by the TEF and adding them together and conservatively including those reported at the detection limits as half the reported detection limit, the TEQ for effluent location NLIN2 was less than 6.5 pg/L on February 22, 2007. On that same date the TEQs were slightly higher at the upstream location CARW2 (>10.0 pg/L) and lower at GEOCRK (5.0 pg/L). All dioxins detected were below the equivalent federal MCL of 30 pg/L. LLNL will continue to monitor storm water concentrations to determine whether trends are emerging.

5.3.5 Environmental Impact of Storm Water

Storm water runoff from the Livermore site did not have any apparent environmental impact in 2007. Tritium activities in storm water runoff effluent were <1% of the drinking water MCL.

Gross alpha and gross beta activities in effluent samples at the Livermore site were both less than their respective MCLs. Site 300 storm water monitoring continues to show low concentrations of dioxins.

5.4 Groundwater

LLNL conducts surveillance monitoring of groundwater in the Livermore Valley and at Site 300 through networks of wells and springs that include off-site private wells and on-site DOE CERCLA wells. To maintain a comprehensive, cost-effective monitoring program, LLNL determines the number and locations of surveillance wells, the analytes to be monitored, the frequency of sampling, and the analytical methods to be used. A wide range of analytes is monitored to assess the impact, if any, of current LLNL operations on local groundwater resources. Because surveillance monitoring is geared to detecting substances at very low concentrations in groundwater, contamination can be detected before it significantly impacts groundwater resources. Groundwater monitoring wells at the Livermore site, in the Livermore Valley, and at Site 300 are included in LLNL's *Environmental Monitoring Plan* (Woods 2005)**.**

Beginning in January 2003, LLNL implemented a new CERCLA comprehensive compliance monitoring plan at Site 300 (Ferry et al. 2002) that adequately covers the DOE requirements for on-site groundwater surveillance. In addition, LLNL continues two additional surveillance networks to supplement the CERCLA compliance monitoring plan and provide additional data to characterize potential impacts of LLNL operations. LLNL monitoring related to CERCLA activities is described in **Chapter 8**. Additional monitoring programs at Site 300 comply with numerous federal and state controls such as state-issued permits associated with closed landfills containing solid wastes and with continuing discharges of liquid waste to sewage ponds and percolation pits; the latter are discussed in **Section 5.2.1**. Compliance monitoring is specified in WDRs issued by the CVRWQCB and in landfill closure and post-closure monitoring plans. (See **Chapter 2**, **Table 2-2** for a summary of LLNL permits.)

The WDRs and post-closure plans specify wells and effluents to be monitored, constituents of concern (COCs) and parameters, frequency of measurement, inspections, and the frequency and form of required reports. These monitoring programs include quarterly and semiannual monitoring of groundwater, monitoring of various influent waste streams, and visual inspections. LLNL performs the maintenance necessary to ensure the physical integrity of closed facilities, such as those that have undergone CERCLA or RCRA closure, and their monitoring networks.

During 2007, representative samples of groundwater were obtained from monitoring wells in accordance with the *LLNL Livermore Site and Site 300 Environmental Restoration Project Standard Operating Procedures* (Goodrich and Wimborough 2006). The procedures cover sampling techniques and information concerning the chemicals that are routinely analyzed for in groundwater. Different sampling techniques were applied to different wells depending on whether they were fitted with submersible pumps or had to be bailed. All of the chemical and radioactivity analyses of groundwater samples were performed by California-certified analytical laboratories.

For comparison purposes only, some of the results were compared with drinking water limits (MCLs). This MCL comparison is used as one way to evaluate groundwater quality, not as a way to determine compliance with Safe Drinking Water Act requirements.

5.4.1 Livermore Site and Environs

5.4.1.1 Livermore Valley

LLNL has monitored tritium in water hydrologically downgradient of the Livermore site since 1988. HTO is potentially the most mobile groundwater contaminant from LLNL operations. Groundwater samples were obtained during 2007 from 24 of 25 water wells in the Livermore Valley (see **Figure 5-4**) and measured for tritium activity. One well could not be sampled during 2007.

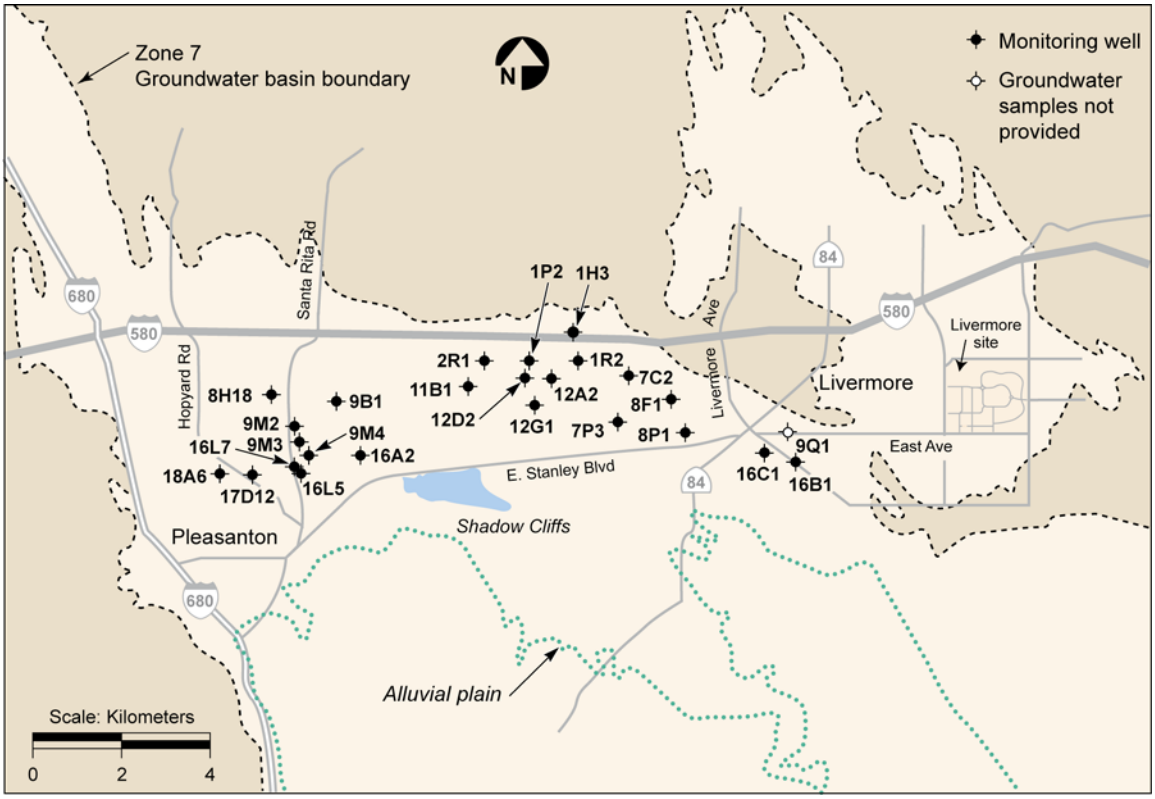

Figure 5-4. Off-site tritium monitoring wells in the Livermore Valley, 2007.

Tritium measurements of Livermore Valley groundwaters are provided in **Appendix A**, **Section A.5**. The measurements continue to show very low and decreasing activities compared with the 740 Bq/L (20,000 pCi/L) MCL established for drinking water in California. The maximum tritium activity measured off site was in the groundwater at well 12D2, located about 6.2 mi west of LLNL (see **Figure 5-4**). The measured activity there was 3.0 Bq/L (81.1 pCi/L) in 2007, less than 0.5% of the MCL.

5.4.1.2 Livermore Site Perimeter

LLNL's groundwater surveillance monitoring program was designed to complement the Livermore Site GWP (see **Chapter 8**). The intent of the program is to monitor for potential groundwater contamination from LLNL operations. The perimeter portion of the surveillance groundwater monitoring network uses three upgradient (background) monitoring wells (wells W-008, W-221, and W-017) near the eastern boundary of the site and seven downgradient monitoring wells located near the western boundary (wells 14B1, W−121, W-151, W-1012, W−571, W-556, and W-373) (see **Figure 5-5**). As discussed in **Chapter 8**, the alluvial sediments have been divided into nine hydrostratigraphic units (HSUs) dipping gently westward. Screened intervals (depth range from which groundwater is drawn) for these monitoring wells range from the shallow HSU-1B to the deeper HSU-5. Two of the background wells, W-008 and W-221, are screened partially in HSU-3A; well W−017 is considered a background well for the deeper HSU-5. To detect contaminants as quickly as possible, the seven western downgradient wells (except well 14B1, screened over a depth range that includes HSU-2, HSU-3A, and HSU−3B) were screened in shallower HSU-1B and HSU-2, the uppermost water-bearing HSUs at the western perimeter. These perimeter wells were sampled and analyzed at least once during 2007 for pesticide and herbicide compounds that are used on- and off-site, for nitrate, for chromium(VI), and for certain radioactive constituents. Analytical results for the Livermore site perimeter wells are provided in **Appendix A**, **Section A.5**.

No pesticide or herbicide organic compounds were detected above analytical reporting limits in groundwater samples from any of the perimeter (upgradient or downgradient) wells during 2007. The inorganic compounds detected include dissolved trace metals and minerals, which occur naturally in the groundwater. Although there have been variations in these concentrations since regular surveillance monitoring began in 1996, the concentrations detected in the 2007 groundwater samples from the upgradient wells represent current background values.

Historically, chromium(VI) has been detected above the MCL (50 µg/L) in groundwater samples from western perimeter well W-373. However, the 2007 sample from this location showed a chromium(VI) concentration of 37 µg/L, continuing the overall downward trend that first dropped below the MCL in 2002.

From 1996 through 2004, concentrations of nitrate detected in groundwater samples from downgradient well W-1012 were greater than the MCL of 45 mg/L. The nitrate concentrations detected in samples from this well during 2007 (33 and 27 mg/L) were again, as in 2006 and 2005, below the MCL. During 2007, concentrations of nitrate in on-site shallow background wells W-008 and W-221 ranged from 26 mg/L to 33 mg/L. Detected concentrations of nitrate in western perimeter wells ranged from 11 mg/L (in well W-373) to 40 mg/L (in well W−151).

No concentrations of plutonium radioisotopes were detected above the radiological laboratory's minimum detectable activities in any of the samples from LLNL's site perimeter wells in 2007. Gross alpha, gross beta, radium-226, and tritium were detected occasionally and at levels consistent with the results from recent years; however, the concentrations again remain well below drinking water MCLs.

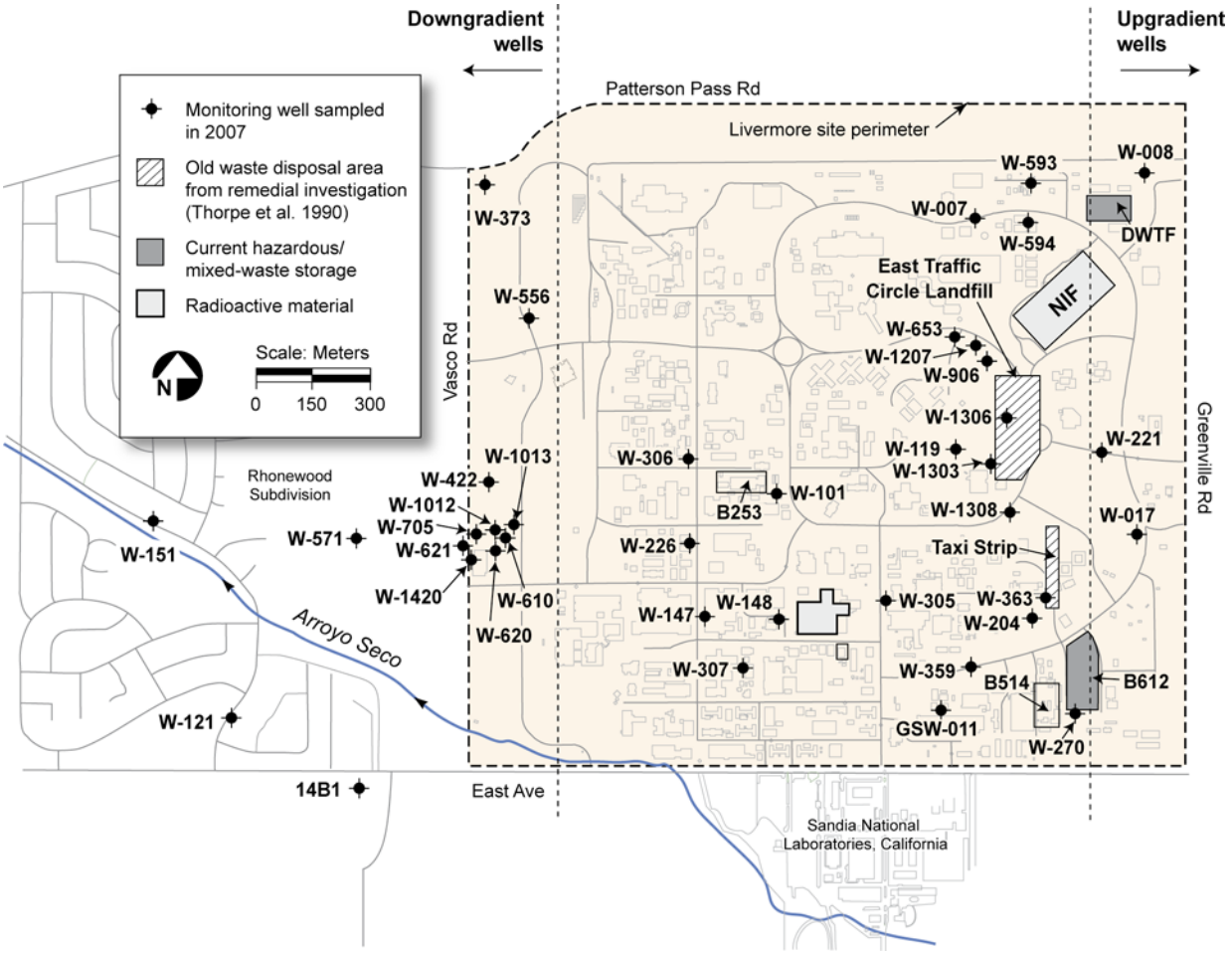

Figure 5-5. Routine surveillance groundwater monitoring wells at the Livermore site, 2007.

5.4.1.3 Livermore Site

Groundwater sampling locations within the Livermore site include areas where releases to the ground may have occurred in the recent past, where previously detected COCs have low concentrations that do not require CERCLA remedial action, and where baseline information needs to be gathered for the area near a new facility or operation. Wells selected for monitoring are screened in the uppermost aquifers and are downgradient from and as near as possible to the potential release locations. Well locations are shown in **Figure 5-5**. All analytical results are provided in **Appendix A**, **Section A.5**.

The Taxi Strip and East Traffic Circle Landfill areas (see **Figure 5-5**) are two potential sources of historical groundwater contamination. Samples from monitoring wells screened in HSU-2 (W-204) and HSU-3A (W-363) downgradient from the Taxi Strip area were analyzed in 2007 for copper, lead, zinc, americium-241, plutonium−238, plutonium-239, radium-226, radium-228, and tritium. Samples from monitoring wells screened at least partially in HSU-2 (W-119, W-906, W-1303, W-1306, and W-1308) within and downgradient from the East Traffic Circle Landfill

were analyzed for the same elements as the Taxi Strip area. No concentrations of americium or plutonium radioisotopes were detected above the radiological laboratory's minimum detectable activities. Concentrations of radium and tritium remained well below the drinking water MCLs. Of the trace metals, only zinc was detected (18 µg/L, reported for well W−906) in any of these seven monitoring wells during 2007.

Although the NIF has not yet begun full operations, LLNL measures pH, conductivity, and tritium concentration of groundwater to establish a baseline. During 2007, tritium analyses were conducted on groundwater samples collected from wells W-653 and W-1207 (screened in HSU-3A and HSU-2, respectively) downgradient of NIF. Samples were also obtained downgradient from the DWTF from wells W-007, W-593, and W-594 (screened in HSU-2/3A, HSU-3A, and HSU-2, respectively) during 2007 and were analyzed for tritium. Monitoring results from the wells near NIF and DWTF showed no detectable concentrations of tritium, above the limit of sensitivity of the analytical method, in the groundwater samples collected during 2007. Monitoring will continue near these facilities to determine baseline conditions.

The former storage area around Building 514 and the hazardous waste/mixed waste storage facilities around Building 612 are also potential sources of contamination. The area and facilities are monitored by wells W-270 and W-359 (both screened in HSU-5), and well GSW-011 (screened in HSU-3A). Groundwater from these wells was sampled and analyzed for general minerals, gross alpha, gross beta, americium-241, plutonium-238, plutonium-239, radium-226, and tritium in 2007. No significant contamination was detected in the groundwater samples collected downgradient from these areas in 2007.

Groundwater samples were obtained from monitoring well W-307 (screened in HSU-1B), downgradient from Building 322. Soil samples previously obtained from this area showed concentrations elevated above the Livermore site's background levels for total chromium, copper, lead, nickel, zinc, and occasionally other metals. LLNL removed contaminated soils near Building 322 in 1999 and replaced them with clean fill. The area was then paved over, making it less likely that metals would migrate from the site. In 2007, the monitoring results for well W-307 showed only slight variations from the concentrations reported in recent years.

Groundwater samples were obtained downgradient from a location where sediments containing metals (including cadmium, chromium, copper, lead, mercury, and zinc) had accumulated in a storm water catch basin near Building 253. In 2007, the samples obtained from monitoring wells W-226 and W-306 (screened in HSU-1B and HSU-2, respectively) contained dissolved chromium at concentrations elevated above background, but concentrations were essentially unchanged from last year.

Additional surveillance groundwater sampling locations, established in 1999, are in areas surrounding the Plutonium Facility and Tritium Facility. Potential contaminants include plutonium and tritium from these facilities, respectively. Plutonium is much more likely to bind to the soils than migrate into the groundwater. Tritium, as HTO, can migrate into groundwater if spilled in sufficient quantities. Upgradient of these facilities, well W−305 is screened in HSU-2;

downgradient wells W-101, W-147, and W-148 are screened in HSU-1B. Groundwater samples collected from these wells during 2007 showed no detectable concentration, above the limit of sensitivity for the analytical method, of either plutonium−238 or plutonium-239+240.

In August 2000, elevated tritium activity was detected in the groundwater sampled at well W-148 (115 ± 5.0 Bq/L [3100 ± 135 pCi/L]). The activity was most likely related to local infiltration of storm water containing elevated tritium activity. Tritium activities in groundwater in this area had remained at or near the same level through 2005, but samples collected from well W-148 in 2006 and 2007 showed significantly lower values—approximately one half the August 2000 value. LLNL continues to collect groundwater samples from these wells periodically for surveillance purposes, primarily to demonstrate that tritium and plutonium contents remain below MCLs.

5.4.2 Site 300 and Environs

For surveillance and compliance groundwater monitoring at Site 300, LLNL uses DOE CERCLA wells and springs on site and private wells and springs off site. Representative groundwater samples are obtained at least once per year at every monitoring location; they are routinely measured for various elements (primarily metals), a wide range of organic compounds, general radioactivity (gross alpha and gross beta), uranium activity, and tritium activity. Groundwater from the shallowest water-bearing zone is the target of most of the monitoring because it would be the first to show contamination from LLNL operations at Site 300.

Brief descriptions of the Site 300 groundwater monitoring networks that are reported in this chapter are given below. (All analytical data from 2007 are included in **Appendix A**, **Section A.6**.)

5.4.2.1 Elk Ravine Drainage Area

The Elk Ravine drainage area, a branch of the Corral Hollow Creek drainage system, includes most of northern Site 300 (see **Figure 5-6**). Storm water runoff in the Elk Ravine drainage area collects in arroyos and quickly infiltrates into the ground. Groundwater from wells in the Elk Ravine drainage area is monitored for COCs to determine the impact of current LLNL operations on the system of underground flows that connects the entire Elk Ravine drainage area. The area contains eight closed landfills, known as Pits 1 through 5 and 7 through 9, and firing tables where explosives tests are conducted. None of the closed landfills has a liner, which is consistent with the disposal practices when the landfills were constructed. The following descriptions of monitoring networks within Elk Ravine begin with the headwaters area and proceed downstream. (See **Chapter 8** for a review of groundwater monitoring in this drainage area conducted under CERCLA.)

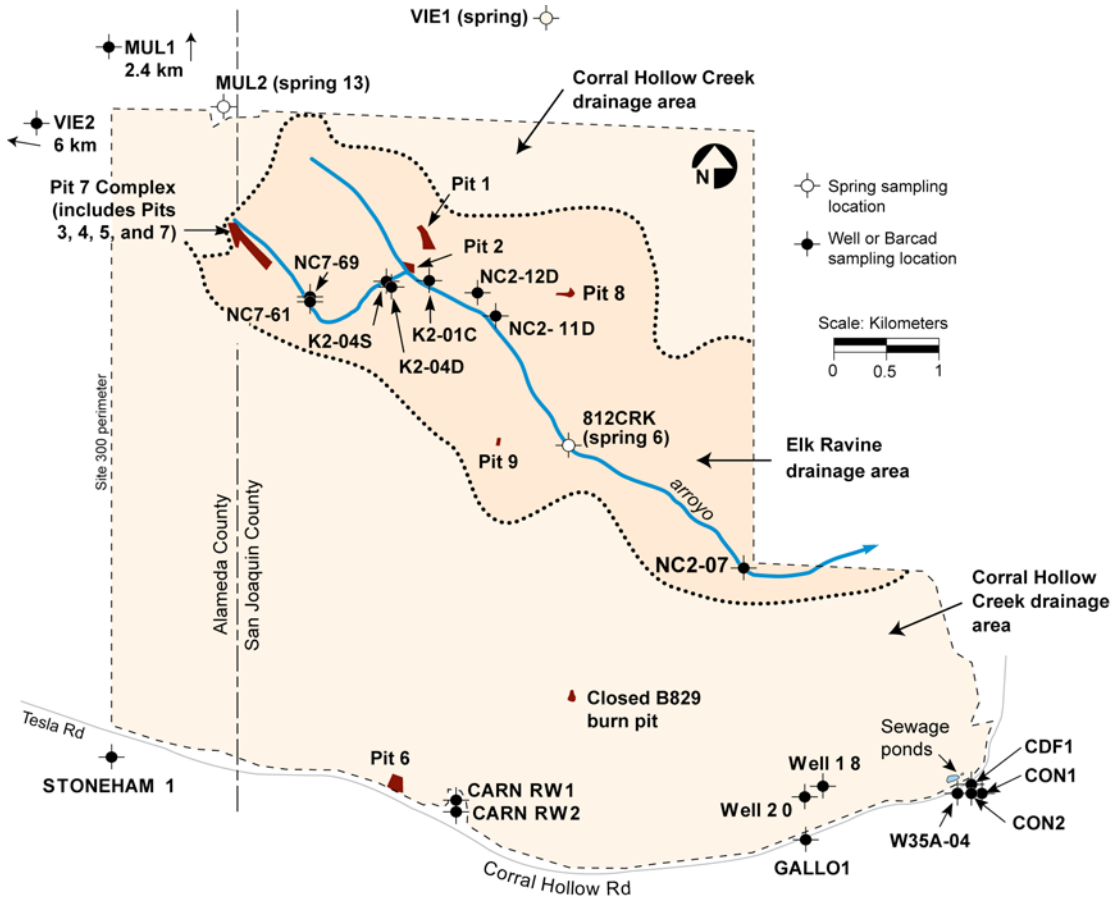

Figure 5-6. Surveillance groundwater wells and springs at Site 300, 2007.

Pit 7 Complex. Monitoring requirements for the Pit 7 landfill, which was closed under RCRA in 1993, are specified in WDR 93-100 administered by the CVRWQCB (1993, 1998) and in *LLNL Site 300 RCRA Closure and Post-Closure Plans—Landfill Pits 1 and 7* (Rogers/Pacific Corporation 1990). The main objective of this monitoring is the early detection of any new release of COCs from Pit 7 to groundwater.

For compliance purposes, LLNL obtained groundwater samples quarterly during 2007 from the Pit 7 monitoring well network. Samples were analyzed for inorganic COCs (mostly metallic elements), general radioactivity (gross alpha and beta), activity of certain radioisotopes (tritium, radium, uranium, and thorium), explosive compounds (HMX and RDX), and VOCs. For a detailed account of Pit 7 compliance monitoring during 2007, including well locations and tables and graphs of groundwater COC analytical data, see Campbell and MacQueen (2008).

Elk Ravine. Groundwater samples were obtained on various dates in 2007 from the widespread Elk Ravine surveillance monitoring network shown in **Figure 5-6** (NC2-07, NC2-11D, NC2-12D, NC7-61, NC7-69, SPRING6 [812CRK], K2-04D, K2-04S, K2-01C). Samples were analyzed for

inorganic constituents (mostly metallic elements), VOCs, general radioactivity (gross alpha and beta), tritium and uranium activity, and explosive compounds (HMX and RDX).

No new release of COCs from LLNL operations in Elk Ravine to groundwater is indicated by the chemical and radioactivity data obtained during 2007. The major source of contaminated groundwater beneath Elk Ravine is from historical operations in the Building 850 firing table area (Webster-Scholten 1994; Taffet et al. 1996). Constituents that are measured as part of the Elk Ravine drainage area surveillance monitoring network are listed in **Appendix B**.

The tritium activity in well NC7-61 decreased from 1200 Bq/L in 2006 to 1080 Bq/L in 2007. This tritium activity remains elevated with respect to the background concentrations. Tritium, as HTO, has been released in the past in the vicinity of Building 850. The majority of the Elk Ravine surveillance network tritium measurements made during 2007 support earlier CERCLA studies that show that the tritium in the plume is diminishing over time because of natural decay and dispersion (Ziagos and Reber-Cox 1998). CERCLA modeling studies indicate that the tritium will decay to background levels before it can reach a site boundary.

Groundwater surveillance measurements of gross alpha, gross beta, and uranium radioactivity in Elk Ravine are all low and are indistinguishable from background levels. (Note that gross beta measurements do not detect the low-energy beta emission from tritium decay.) Additional detections of nonradioactive elements including arsenic, barium, chromium, selenium, vanadium, and zinc are all within the natural ranges of concentrations typical of groundwater elsewhere in the Altamont Hills.

Pit 1. Monitoring requirements for the Pit 1 landfill, which was closed under RCRA in 1993, are also specified in WDR 93-100 administered by the CVRWQCB (1993, 1998) and in Rogers/Pacific Corporation (1990). The main objective of this monitoring is the early detection of any release of COCs from Pit 1 to groundwater. LLNL obtained groundwater samples quarterly during 2007 from the Pit 1 monitoring well network. Samples were analyzed for inorganic COCs (mostly metallic elements), general radioactivity (gross alpha and beta), activity of certain radioisotopes (tritium, radium, uranium, and thorium), explosive compounds (HMX and RDX), and VOCs (EPA Methods 601 and 8260). Additional annual analyses were conducted on groundwater samples for extractable organics (EPA Method 625), as well as pesticides and PCBs (EPA Method 608). Compliance monitoring showed no new releases at Pit 1 in 2007; a detailed account of Pit 1 compliance monitoring during 2007, including well locations and tables and graphs of groundwater COC analytical data, is in Campbell and MacQueen (2008).

5.4.2.2 Corral Hollow Creek Drainage Area

Pit 6. Compliance monitoring requirements for the closed Pit 6 landfill in the Corral Hollow Creek drainage area are specified in Ferry et al. (1998, 2002). Two Pit 6 groundwater monitoring programs, which operate under CERCLA, ensure compliance with all regulations. They are (1) the Detection Monitoring Plan (DMP), designed to detect any new release of COCs to groundwater from wastes buried in the Pit 6 landfill, and (2) the Corrective Action Monitoring Plan (CAMP), which monitors the movement and fate of historical releases. To comply with

monitoring requirements, LLNL obtained groundwater samples monthly, quarterly, semiannually, and annually during 2007 from specified Pit 6 monitoring wells. No new releases were detected at Pit 6 in 2007; a detailed account of Pit 6 compliance monitoring during 2007, including well locations, tables of groundwater analytical data, and maps showing the distribution of COC plumes, is in Campbell and Taffet (2008).

Building 829 Closed High Explosives Burn Facility. Compliance monitoring requirements for the closed burn pits in the Corral Hollow Creek drainage area are specified in Mathews and Taffet (1997), and in LLNL (2001), as modified by DTSC (2003). As planned for compliance purposes, LLNL obtained groundwater samples during 2007 from the three wells in the Building 829 monitoring network. Groundwater samples from these wells, screened in the deep regional aquifer, were analyzed for inorganics (mostly metals), general minerals, turbidity, explosive compounds (HMX, RDX, and TNT), VOCs (EPA Method 624), extractable organics (EPA Method 625), pesticides (EPA Method 608), herbicides (EPA Method 615), general radioactivity (gross alpha and beta), radium activity, total organic carbon (TOC), total organic halides (TOX), and coliform bacteria.

During 2007, there were no confirmed COC detections above their respective statistical limits in groundwater samples from any of the Building 829 network monitoring wells. Among the inorganic constituents, perchlorate was not detected above its reporting limit in any sample. The metal COCs that were detected showed concentrations that are not significantly different from background concentrations for the deep aquifer beneath the HE Process Area. Similarly, all results for gross alpha and gross beta (the radioactive COCs) were below their statistical limit values. There were no organic or explosive COCs detected above reporting limits in any samples. For a detailed account of compliance monitoring of the closed burn pit during 2007, including well locations and tables and graphs of groundwater COC analytical data, see Revelli (2008b).

Water Supply Well. Water supply well 20, located in the southeastern part of Site 300 (**Figure 5-6**), is a deep, high-production well. The well is screened in the Neroly lower sandstone aquifer (Tnbs1) and can produce up to 1500 L/min (396 gal/min) of potable water. As planned for surveillance purposes, LLNL obtained groundwater samples quarterly during 2007 from well 20. Groundwater samples were analyzed for inorganic COCs (mostly metals), VOCs, general radioactivity (gross alpha and gross beta), and tritium activity. Quarterly measurements of groundwater from well 20 do not differ significantly from previous years. As in past years, the primary potable water supply well at Site 300 showed no evidence of contamination. Gross alpha, gross beta, and tritium activities were very low and are indistinguishable from background level activities.

5.4.2.3 Off-site Surveillance Wells and Springs

As planned for surveillance purposes, during 2007 LLNL obtained groundwater samples from two off-site springs (MUL2 and VIE2) and ten off-site wells (MUL1, VIE1, CARNRW1, CARNRW2, CDF1, CON1, CON2, GALLO1, STONEHAM1, and W35A-04) **(Figure 5-6)**. With the exception of one well, all off-site monitoring locations are near Site 300. The exception,

well VIE2, is located at a private residence 6 km west of the site. It represents a typical potable water supply well in the Altamont Hills.

Samples from CARNRW2, CDF1, CON1, and GALLO1 were analyzed quarterly for inorganic COCs (mostly metals), general radioactivity (gross alpha and beta), tritium activity, explosive compounds (HMX and RDX), and VOCs (EPA method 502.2). Additional annual analyses were conducted on third-quarter samples for uranium activity and extractable organic compounds (EPA Method 625) for samples collected from CARNRW2 only. In addition, CARNRW1 and CON2 samples were analyzed for VOCs; samples from well CARNRW1 were also sampled for perchlorate and tritium.

Groundwater samples were obtained once (annually) during 2007 from the remaining off-site surveillance monitoring locations: MUL1, MUL2, and VIE1 (north of Site 300); VIE2 (west of Site 300); and STONEHAM1 and W-35A-04 (south of Site 300). Samples were analyzed for inorganic COCs (metals, nitrate, and perchlorate), general radioactivity (gross alpha and beta), tritium and uranium activity, explosive compounds (HMX and RDX), VOCs, and extractable organic compounds (EPA Method 625).

5.5 Other Monitoring Programs

5.5.1 Rainwater

Rainwater is sampled and analyzed for tritium activity in support of DOE Order 5400.5. Rainwater is collected in stainless-steel buckets at fixed locations. The tritium activity of each sample is measured and all analytical results are provided in **Appendix A**, **Section A.7**.

5.5.1.1 Livermore Site and Environs

Rain sampling locations are shown in **Figure 5-7**. During 2007, LLNL collected rainwater samples following one rain event in the Livermore Valley. All of the rainwater sampling dates correspond to storm water runoff sampling. During 2007, no on-site measurement of tritium activity was above the MCL of 740 Bq/L (20,000 pCi/L) established by the EPA for drinking water. As in past years, the on-site rainwater sampling location B343 showed the highest tritium activity for the year, 23 Bq/L (622 pCi/L), for the rain event that was sampled on February 26. The maximum tritium activity measured in off-site rainwater samples during 2007 were estimated values below the minimum reporting limit of 3.7 Bq/L (100 pCi/L).

5.5.1.2 Site 300 and Environs

During 2007, LLNL collected rainwater samples following one rain event at Site 300. Two on-site locations (COMP and TNK5) were positioned to collect rainfall for tritium activity measurements at Site 300 during 2007 (see **Figure 5-3**). As in past years, none of the rainwater samples from monitoring locations at Site 300 during 2007 showed tritium activities above the analytical laboratory reporting limit.

5.5.2 Livermore Valley Surface Waters

LLNL conducts additional surface water surveillance monitoring in support of DOE Order 5400.5. Surface and drinking water near the Livermore site and in the Livermore Valley were sampled at the locations shown in **Figure 5-7** in 2007. Off-site sampling locations CAL, DEL, DUCK, ALAG, SHAD, and ZON7 are surface water bodies; of these, CAL, DEL, and ZON7 are also drinking water sources. GAS and TAP are drinking water outlets. Radioactivity data from drinking water sources are used to calculate drinking water statistics (see **Table 5-7**).

Samples are analyzed according to written, standardized procedures summarized in Woods (2005). LLNL sampled these locations semiannually in 2007 for gross alpha, gross beta, and tritium. All analytical results are provided in **Appendix A**, **Section A.7**.

The median activity for tritium in surface and drinking waters was estimated from calculated values to be below the analytical laboratory's minimum detectable activities, or minimum quantifiable activities. The maximum tritium activity detected in any sample collected in 2007 was 2.35 Bq/L (63.5 pCi/L), less than 1% of the drinking water MCL. Median activities for gross alpha and gross beta radiation in surface and drinking water samples were both less than 5% of their respective MCLs. Maximum activities detected for gross alpha and gross beta radioactivity, respectively, were 0.194 Bq/L (5.24 pCi/L) and 0.374 Bq/L (10.11 pCi/L); both were less than 35% of their respective MCLs (see **Table 5-7**). Historically, concentrations of gross alpha and gross beta radiation have fluctuated around the laboratory's minimum detectable activities. At these very low levels, the counting error associated with the measurements is nearly equal to, or in many cases greater than, the calculated values so that no trends are apparent in the data.

5.5.3 Lake Haussmann Release

Lake Haussmann can hold approximately 45.6 million L (37 acre-feet) of water and is located near the center of the Livermore site. It collects treated groundwater from surrounding groundwater treatment facilities TFD and TFE and portable treatment units, and from storm water runoff. Previous LLNL environmental reports detail the history of the construction and management of Lake Haussmann, the regulatory drivers, sampling requirements, and discharge limits (see Harrach et al. 1995, 1996, 1997). LLNL collects discharge samples at location CDBX (**Figure 5-2)** and compares them with samples collected at location WPDC to identify any change in water quality. Written, standardized sample collection procedures are summarized in Woods (2005). State-certified laboratories analyze the collected samples for chemical and physical parameters. All analytical results are included in **Appendix A**, **Section A.7**.

The only limit exceeded for samples collected at CDBX and WPDC was the pH discharge limit of 8.5. Dry season and wet season pH has averaged 9.3 and 8.3, respectively, since 1992. The higher pH readings seen in Lake Haussmann discharge samples during the dry season correspond to the peak of the summer algal bloom within Lake Haussmann. During 2007, total dissolved solids and specific conductance continued to reflect the levels found in groundwater discharged to Lake Haussmann. While some metals were detected, no metals were above discharge limits. All organics and PCBs were below analytical detection limits. Pesticides, gross alpha, gross beta, and

tritium levels were well below discharge limits. Aquatic bioassays for toxicity showed no effects in Lake Haussmann discharge water.

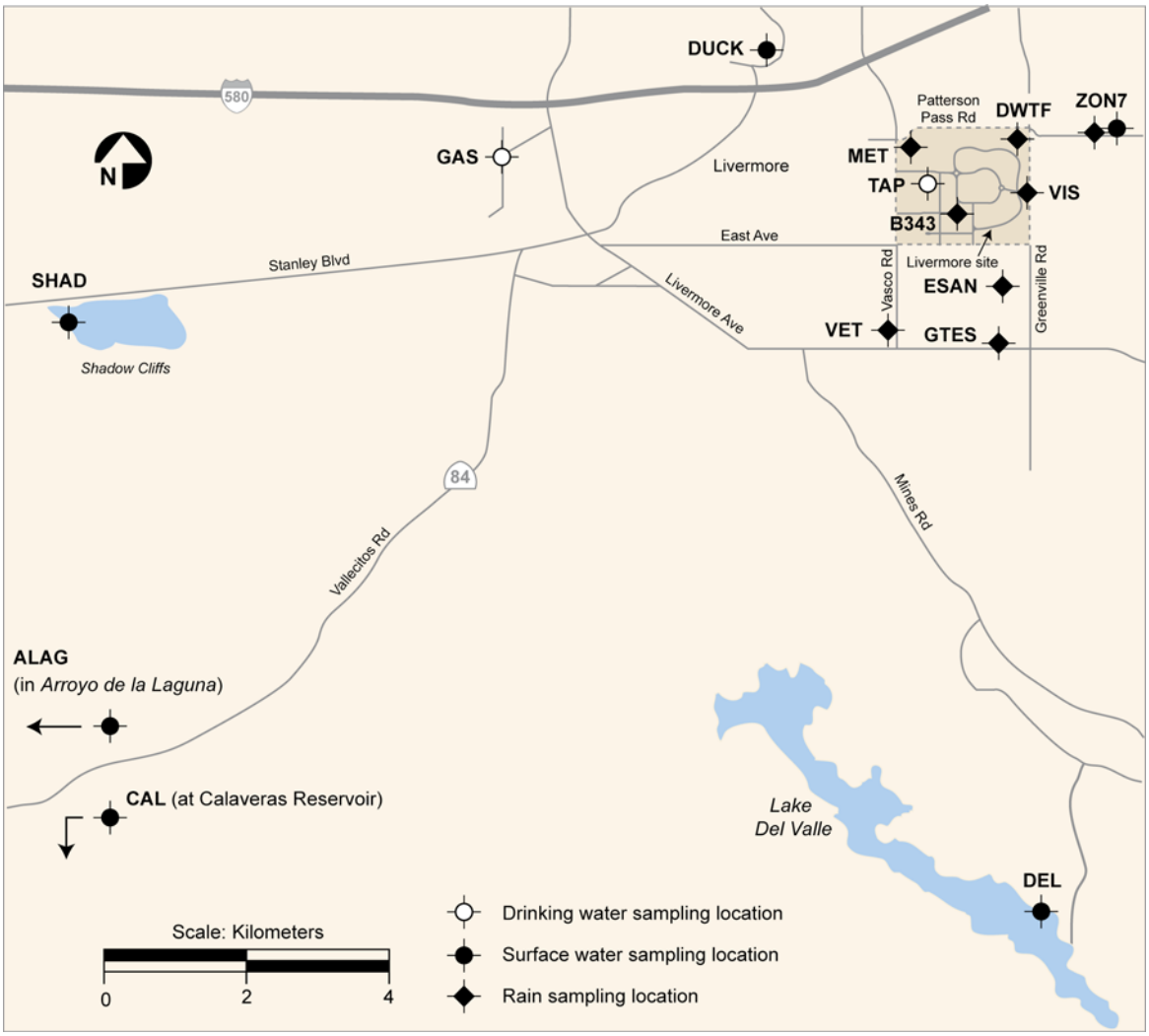

Figure 5-7. Livermore site and Livermore Valley sampling locations for rain, surface water, and drinking water, 2007.

Table 5-7. Radioactivity in surface and drinking waters in the Livermore Valley, 2007.

Location	Metric	Tritium (Bq/L)[a]	Gross alpha (Bq/L)[a]	Gross beta (Bq/L)[a]
All locations	Median	0.65	0.0069	0.081
	Minimum	–1.57	–0.045	–0.0033
	Maximum	2.35	0.194	0.374
	Interquartile range	2.49	0.044	0.052
Drinking water locations	Median	0.88	0.021	0.047
	Minimum	–0.96	–0.038	–0.0033
	Maximum	2.35	0.098	0.079
	Drinking water MCL	740	0.555	1.85

(a) A negative number means the sample radioactivity was less than the background radioactivity.

5.5.4 Site 300 Drinking Water System Discharges

LLNL samples large-volume discharges from the Site 300 drinking water distribution system that reach surface water drainage courses in accordance with the requirements of WDR 5-00-175, NPDES General Permit No. CAG995001. The monitoring and reporting program that LLNL developed for these discharges was approved by the CVRWQCB. Discharges that are subject to these sampling and monitoring requirements are:

- Drinking water storage tanks: Discharges that have the potential to reach surface waters are monitored.
- System flushes: One flush per pressure zone per year is monitored for flushes that have the potential to reach surface waters.
- Dead-end flushes: All flushes that have the potential to reach surface waters and any discharge that continues for more than four months are monitored.

Complete monitoring results from 2007 are detailed in the quarterly self-monitoring reports to the CVRWQCB. The annual testing, required by the CVRWQCB, was completed during the third quarter when LLNL conducted flushing of the drinking water system for water quality purposes. These system flush releases were monitored and met the effluent limits. All 2007 releases from the Site 300 drinking water system reaching surface waters quickly percolated into the drainage ditches or streambed and did not reach Corral Hollow Creek, the potential receiving water.

5.5.5 Percolation Pits

Percolation pits designed to accept discharges from mechanical equipment are located at Site 300 Buildings 806A, 827A, 827C, 827D, and 827E. These discharges are permitted by WDR 96-248, which specifies monthly observations and monitoring requirements for overflows of the percolation pits. In other Site 300 facilities, these types of waste streams are discharged to septic systems. If an overflow occurs, it is sampled and analyzed to determine concentrations of any metals present. During 2007, all of the percolation pits operated normally with no overflows.

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6. Terrestrial Monitoring

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Lawrence Livermore National Laboratory monitors several aspects of the terrestrial environment. LLNL measures the radioactivity present in soil, vegetation, and wine, and the absorbed gamma radiation dose at ground-level receptors from terrestrial and atmospheric sources.

The LLNL terrestrial radioactivity monitoring program is designed to measure any changes in environmental levels of radioactivity. All monitoring activities follow U.S. DOE guidance criteria. On-site monitoring activities detect radioactivity released from LLNL that may contribute to radiological dose to the public or to biota; monitoring at distant locations not impacted by LLNL operations detects naturally occurring background radiation.

Terrestrial pathways from LLNL operations leading to potential radiological dose to the public include resuspension of soils, infiltration of constituents of runoff water through arroyos to groundwater, ingestion of locally grown foodstuffs, and external exposure to contaminated surfaces and radioactivity in air. Potential ingestion doses are calculated from measured concentrations in vegetation and wine; doses from exposure to ground-level external radiation are obtained directly from thermoluminescent dosimeters (TLDs) deployed for environmental radiation monitoring. Potential dose to biota (see **Chapter 7**) is calculated using a screening model that requires knowledge of radionuclide concentrations in soils, sediments, and surface water.

Sampling for all media is conducted according to written, standardized procedures summarized in Woods (2005).

In addition to terrestrial radioactivity monitoring, LLNL monitors the abundance, distribution, and ecological requirements of plant and wildlife species, and conducts research relevant to the protection of rare plants and animals. Monitoring and research of biota on LLNL property is conducted to ensure compliance with requirements of the U.S. Endangered Species Act, the California Endangered Species Act, the Eagle Protection Act, the Migratory Bird Treaty Act, and other applicable regulations as they pertain to endangered, threatened, and other special status species, their habitats, and designated critical habitats that exist at both LLNL sites.

6.1 Soil and Sediment Monitoring

The number of soil and sediment sampling locations are as follows:

Livermore site—6 soil, 4 sediment (see **Figure 6-1**)

Livermore Valley—10 soil, including 3 at the WRD (see **Figure 6-2**)

Site 300—14 soil (see **Figure 6-3**)

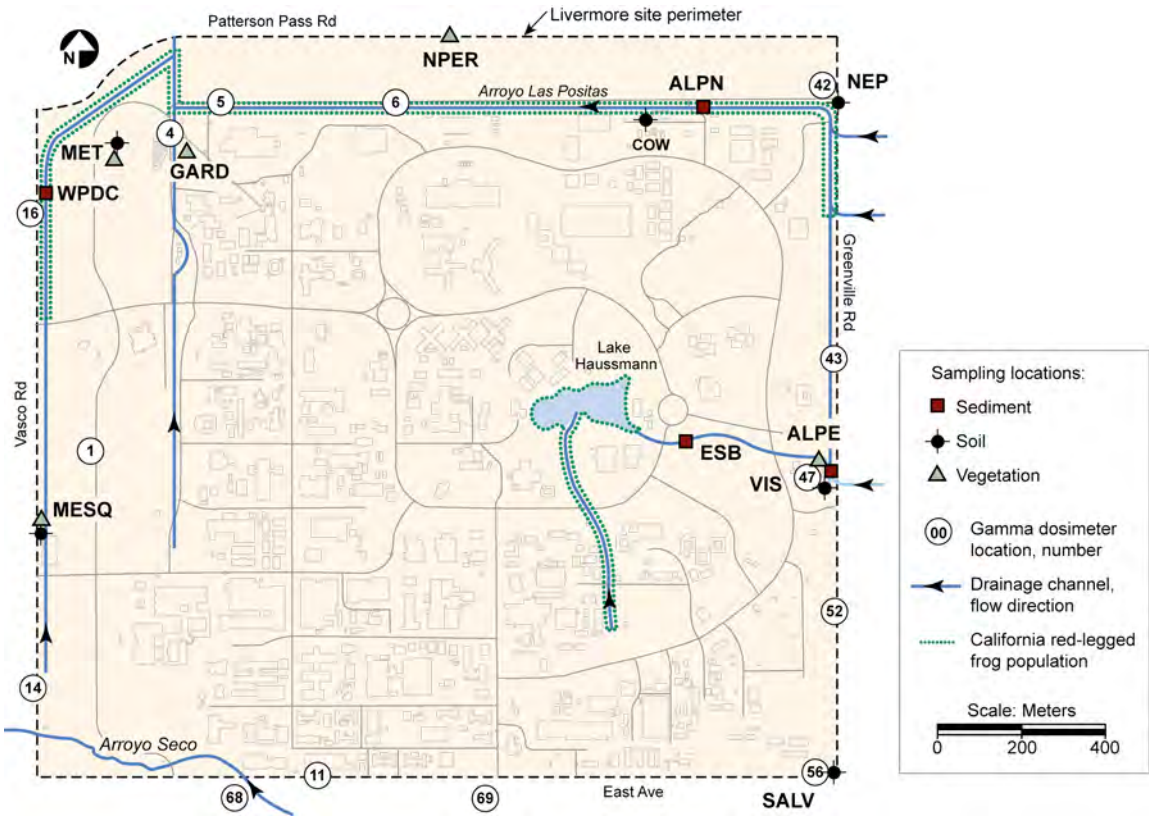

Figure 6-1. Sampling locations and populations of the California red-legged frog, a threatened species, Livermore site, 2007.

These locations were selected to represent background concentrations (distant locations unlikely to be affected by LLNL operations) as well as areas with the potential to be affected by LLNL operations. Sampling locations also include areas with known contaminants, such as the WRD and around explosives testing areas at Site 300.

Surface sediment and vadose zone soil samples are collected from selected arroyos and other drainage areas on and around the Livermore site. These sampling locations, shown in **Figure 6-1,** coincide largely with selected LLNL storm water sampling locations (see **Chapter 5**).

Surface soil samples are collected from the top 5 cm of soil because aerial deposition is the primary pathway for potential contamination, and resuspension of materials from the surface into the air is the primary exposure pathway to nearby human populations. Two 1-m squares are chosen from which to collect the sample. Each sample is a composite consisting of 10 subsamples that are collected at the corners and center of each square by an 8.25-cm-diameter, stainless-steel core sampler.

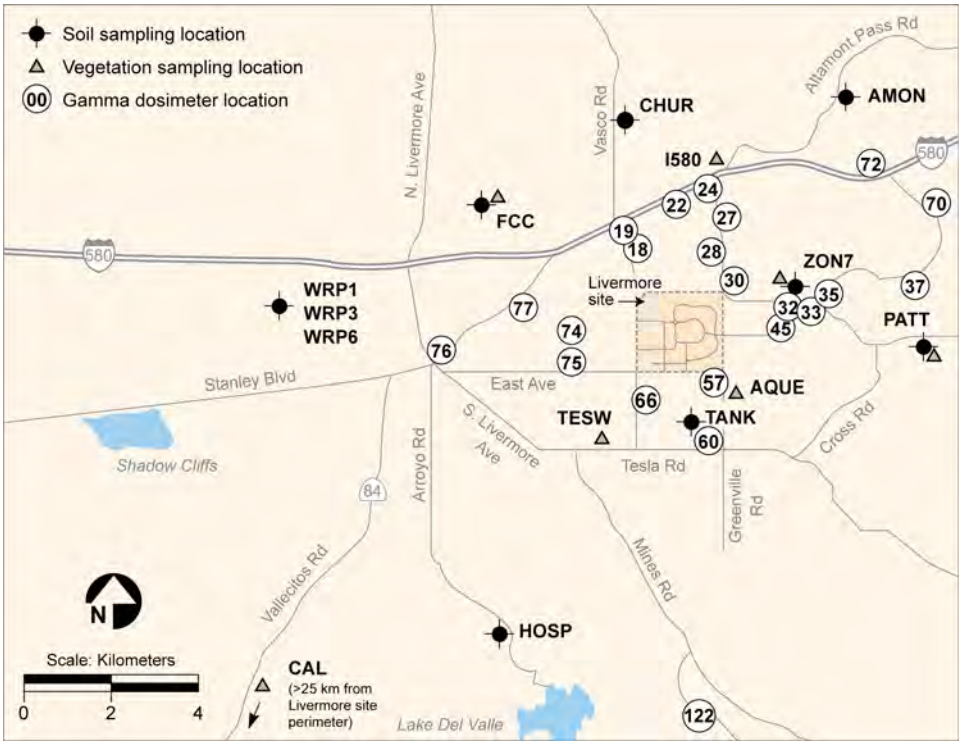

Figure 6-2. Sampling locations and gamma dosimeter locations, Livermore Valley, 2007.

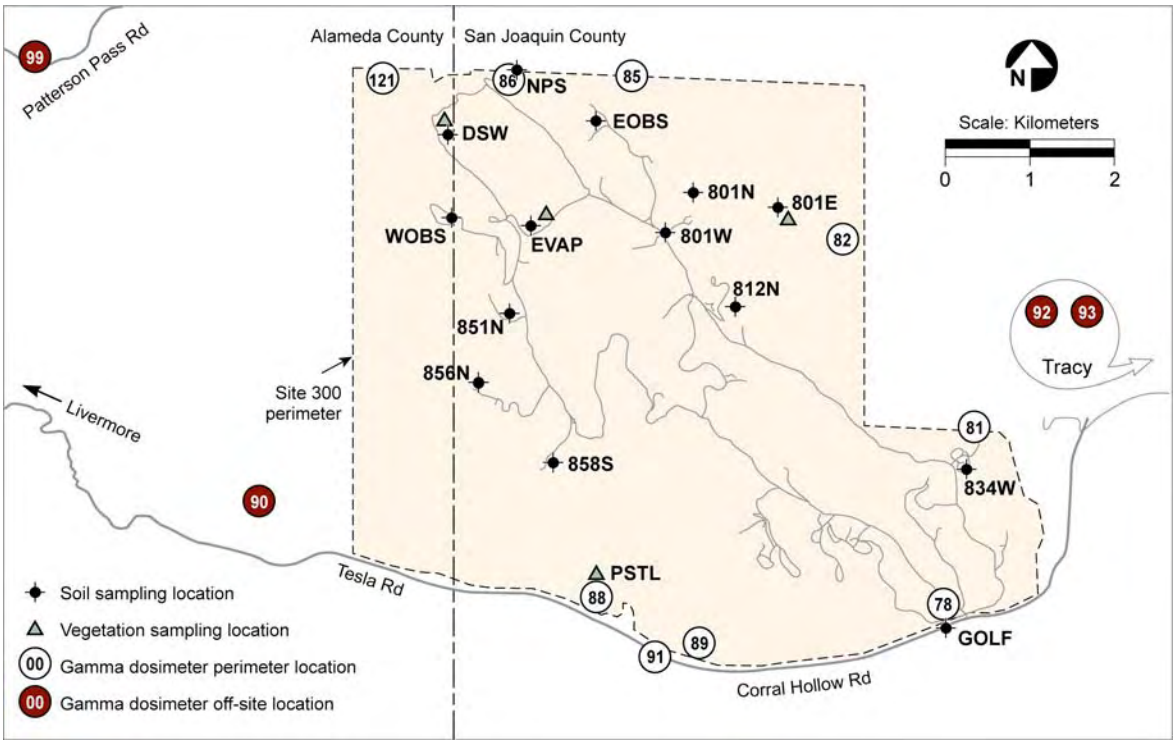

Figure 6-3. Sampling locations at Site 300 and off-site, 2007.

Surface sediment samples are collected in a similar manner. Ten subsamples, 5-cm deep, are collected at 1-m intervals along the transect of an arroyo or drainage channel. At one of the subsample locations, a 15-cm deep sample is taken for tritium analysis; this deeper sample is necessary to obtain sufficient water in the sample for tritium analysis. Vadose zone samples are collected at the same location as the tritium subsample but at deeper positions; a 30- to 45-cm deep sample is collected for metals analysis, and a 45- to 65-cm deep sample is collected for analysis for PCBs.

In 2007, surface soil samples in the Livermore Valley were analyzed for plutonium and gamma-emitting radionuclides. Samples from Site 300 were analyzed for gamma-emitting radionuclides and beryllium. Annual sediment samples collected at the Livermore site were analyzed for plutonium, gamma-emitting radionuclides, and tritium. Vadose zone samples were collected at the four sediment sampling locations and were analyzed for total and soluble metals; one vadose zone location was analyzed for PCBs.

Prior to radiochemical analysis, surface soil and sediment samples are dried, sieved, ground, and homogenized. The plutonium content of a 100-g sample aliquot is determined by alpha spectrometry. Other sample aliquots (300 g) are analyzed by gamma spectrometry using a high-purity germanium (HPGe) detector for 47 radionuclides, including fission products, activation products from neutron interactions on steel, actinides, and natural products. For beryllium, 10-g subsamples are analyzed by atomic emission spectrometry. Vadose zone soil samples are analyzed by standard EPA methods.

6.1.1 Radiological Monitoring Results

The 2007 data on the concentrations of radionuclides in surface soil and sediment from the Livermore Valley sampling locations are provided in **Appendix A**, **Section A.8**.

The concentrations and distributions of all observed radionuclides in soil for 2007 are within the ranges reported in previous years and generally reflect worldwide fallout and naturally occurring concentrations. Slightly higher values at and near the Livermore site have been attributed to historical operations (Silver et al. 1974), including the operation of solar evaporators for plutonium-containing liquid waste in the southeast quadrant of the site. LLNL ceased operating the solar evaporators in 1976 and no longer engages in any other open-air treatment of plutonium-containing waste. Sampling at location ESB, which is in the drainage area for the southeast quadrant of the Livermore site, shows the effects of the historical operation of solar evaporators. The measured value for plutonium-239+240 at this location in 2007 was 1.5 mBq/dry g (4.1×10^{-2} pCi/dry g). Elevated levels of plutonium-239+240 resulting from an estimated 1.2×10^{9} Bq (32 mCi) plutonium release to the sanitary sewer in 1967 and earlier releases were again detected at WRD sampling locations in 2007. The highest detected plutonium-239+240 value at the WRD was 7.0 mBq/dry g (1.9×10^{-1} pCi/dry g). In addition, americium-241 was detected in one WRD sample at a concentration of 2.9 mBq/dry g (7.8×10^{-2} pCi/dry g) and was most likely caused by the natural radiological decay of the trace concentrations of plutonium-241 that were present in these historical releases to the sewer.

The highest detected value for tritium in 2007 (6.8 Bq/L [180 pCi/L]) was at location ALPN, which is downwind of the Tritium Facility. In 2007, tritium emissions were consistent with the Tritium Facility's associated operations, as described in **Chapter 4**. All tritium concentrations were within the range of previous data.

The soils data for Site 300 for 2007 are provided in **Appendix A**, **Section A.8**. The concentrations and the distributions of all radionuclides observed in Site 300 soil for 2007 lie within the ranges reported in all years since monitoring began. At 13 of the 14 sampling locations, the ratio of uranium-235 to uranium-238 reflects the natural ratio of 0.00725. There is significant uncertainty in calculating the ratio, however, due to the difficulty of measuring low activities of uranium-238 by gamma spectrometry. The highest measured values for uranium-235 and uranium-238 in a single sample were 0.36μg/g (0.029 Bq/g or 0.78 pCi/g) and 170 μg/g (2.1 Bq/g or 57 pCi/g), respectively. The uranium-235 to uranium-238 ratio in this sample is 0.0021, which at the levels of uncertainty associated with the analysis equals the ratio for depleted uranium of 0.002. Such values at Site 300 result from the use of depleted uranium in explosive experiments.

6.1.2 Nonradiological Monitoring Results

Analytical results for metals are compared with site-specific natural background concentrations for metals. (See **Appendix A**, **Section A.8**, for background concentrations for both the Livermore site and Site 300 and analytical results for metals.)

All metal concentrations at the Livermore site were within site background values with the exception of total and soluble zinc at location ESB. Livermore site groundwater surveillance monitoring (see **Chapter 5**) determines the impact of these metals, if any, on-site groundwater.

Aroclor 1260, a PCB, has been detected at location ESB since surveillance for PCBs began at this location in 2000. In 2007, the concentration was 1.1 mg/kg. The presence of PCBs suggests residual low-level contamination from the 1984 excavation of the former East Traffic Circle landfill (see **Chapter 5**). The detected concentrations are below the federal and state hazardous waste limits.

Beryllium results for soils at Site 300 were within the ranges reported since sampling began in 1991. The highest value, 9.1 mg/kg, was found in an area that has historically been used for explosives testing. This value is much lower than the 110 mg/kg detected in 2003. The differing results reflect the particulate nature of the contamination.

6.1.3 Environmental Impact on Soil and Sediment

6.1.3.1 Livermore Site

Routine surface soil, sediment, and vadose zone soil sample analyses indicate that the impact of LLNL operations on these media in 2007 has not changed from previous years and remains insignificant. Most analytes of interest or concern were detected at background concentrations or in trace amounts or could not be measured above detection limits.

The highest value for plutonium-239+240 in 2007 (7.0 mBq/dry g [0.19 pCi/dry g]), measured at WRD, is 1.5% of the National Council on Radiation Protection (NCRP) recommended screening limit of 470 mBq/g (12.7 pCi/g) for property used for commercial purposes (NCRP 1999).

LLNL has investigated the presence of radionuclides in local soils frequently over the years including possible impacts of the distribution to the public of sludge contaminated by the 1967 plutonium release (see Table 6-5 in the *Environmental Report 2006* [Mathews et al. 2007] for a list of previous studies.) The studies have consistently shown that the concentrations of radionuclides in local soils are below levels of health concern. In fact, the concentrations are of such low levels of health concern that the Agency for Toxic Substances and Disease Registry (ATSDR) (2003) strongly recommended against further study of local soils for the purpose of identifying locations where plutonium-contaminated sludge from the 1967 release may remain.

6.1.3.2 Site 300

The concentrations of radionuclides and beryllium detected in soil samples collected at Site 300 in 2007 are within the range of previous data and are generally representative of background or naturally occurring levels. The uranium−235/uranium-238 ratios that are indicative of depleted uranium occurred near the firing tables. They result from the fraction of the firing table operations that disperse depleted uranium. The highest measured uranium-238 concentration was 170 µg/g (2.1 Bq/g or 57 pCi/g) and was well below the NCRP-recommended screening level for commercial sites (313 µg/g [3.9 Bq/g or 105 pCi/g]). These values occurred near Bunker 812 and are a result of historic operations at that location. A CERCLA Remedial Investigation/Feasibility Study report for Bunker 812 will be submitted to the regulatory agencies in 2008. This Investigation/Feasibility Study specifies the nature and extent of contamination, risk assessment, and remedial alternatives for CERCLA cleanup of the site (see **Chapter 8**).

6.2 Vegetation and Foodstuff Monitoring

Vegetation sampling locations at the Livermore site (see **Figure 6-1**) and in the Livermore Valley (see **Figure 6-2**) are divided for comparison into the following three groups:

- Near locations (AQUE, GARD, MESQ, NPER, MET, and VIS) are on-site or less than 1 km from the Livermore site perimeter.
- Intermediate locations (I580, PATT, TESW, and ZON7) are in the Livermore Valley and 1 to 5 km from the Livermore site perimeter.
- Far locations (FCC and CAL) are more than 5 km from the Livermore site perimeter; FCC is about 5 km away and CAL is more than 25 km away. Both locations are generally upwind of the Livermore site.

Tritium in vegetation due to LLNL operations is most likely to be detected at the Near and Intermediate locations and is highly unlikely to be detected at the Far locations.

Site 300 has four monitoring locations for vegetation (PSTL, 801E, DSW, and EVAP) (see **Figure 6-3**). Vegetation at locations DSW and EVAP exhibit variable tritium concentrations due to occasional uptake of contaminated groundwater by the roots. At the other two locations, 801E and PSTL, the only likely potential source of tritium uptake is the atmosphere, although groundwater in the vicinity of PSTL is contaminated with low levels of tritium.

Vegetation is sampled and analyzed quarterly. Water is extracted from vegetation by freeze-drying and analyzed for tritiated water (HTO) using liquid scintillation techniques.

Wines for sampling in 2007 were purchased from supermarkets in Livermore. The wines represent the Livermore Valley, two other regions of California, and the Rhone Valley in France. Wines were prepared for sampling using a method that separates the water fraction from the other components of the wine and were analyzed using an ultra-low-level scintillation counter.

6.2.1 Vegetation Monitoring Results

Median and mean concentrations of tritium in vegetation based on samples collected at the Livermore site, in the Livermore Valley, and Site 300 in 2007 are shown in **Table 6-1**. (See **Appendix A**, **Section A.9**, for quarterly tritium concentrations in plant water). The highest mean tritium concentration for 2007 was 22 Bq/L at the Intermediate location TESW located approximately 2 km southwest of the Livermore site. For Site 300, the highest mean concentration for 2007 was 99 Bq/L at EVAP located in an area where the groundwater is contaminated with tritium.

Median concentrations of tritium in vegetation at sampling locations at the Livermore site and in the Livermore Valley have decreased noticeably since 1989 (see **Figure 6-4**). Median concentrations at the Far locations have been below the detection limit of approximately 2.0 Bq/L since 1993. Median concentrations at the Intermediate locations have been below the detection limit since 1998, except in 2002 when the median concentration was 2.3 Bq/L. Median concentrations at the near locations were below detection limit between 2003 and 2005 and more recently have been slightly above the detection limit.

At Site 300, the median concentrations of tritium in vegetation at locations 801E, DSW and PSTL were below detection limit. The median concentration of tritium in vegetation at EVAP was 82 Bq/L.

6.2.2 Wine Monitoring Results

Analysis of the wines purchased in 2007 demonstrates the same relationship between the Livermore Valley, California (other than the Livermore Valley), and the Rhone Valley (France) wines that has been seen routinely in the past. Concentrations of tritium in California wines are low and reflect residual historical bomb fallout and cosmogenic tritium levels; concentrations in Livermore Valley wines range from the low levels seen in California wines to the higher levels seen in Rhone Valley wines; and the concentrations in both of the Rhone Valley wines is higher than any of the Livermore Valley wines (see **Table 6-2**). The highest concentration in a

Livermore Valley wine sampled in 2007 (2.1 Bq/L [57 pCi/L]) was from a wine made from grapes harvested in 2005.

Table 6.1. Median and mean concentrations of tritium in plant water for the Livermore site, Livermore Valley, and Site 300 sampled in 2007. The table includes mean annual ingestion doses calculated for 2007.

Sampling locations		Concentration of tritium in plant water (Bq/L)		Mean annual ingestion dose[a] (nSv/y)
		Median	Mean	
NEAR (on-site or <1 km from Livermore site perimeter)	AQUE	1.3	1.3	<10[b]
	GARD	2.2	2.6	13
	MESQ	2.2	7.3	36
	MET	1.5	1.5	<10[b]
	NPER	3.2	4.3	21
	VIS	2.5	7.2	35
INTERMEDIATE (1–5 km from Livermore site perimeter)	I580	1.2	1.2	<10[b]
	PATT	0.59	0.62	<10[b]
	TESW	1.4	22	110
	ZON7	1.1	0.81	<10[b]
FAR (>5 km from Livermore site perimeter)	CAL	0.35	0.34	<10[b]
	FCC	0.01	-0.048	<10[b]
Site 300	801E	1.1	1.2	(c)
	DSW[d]	0.18	1.6	(c)
	EVAP[d]	82	99	(c)
	PSTL	-0.46	-0.31	(c)

(a) Ingestion dose is based on conservative assumptions that an adult's diet is exclusively vegetables with this tritium concentration, and that meat and milk are derived from livestock fed on grasses with the same concentration of tritium. See **Table 6-3**.

(b) When concentrations are less than the detection limit (about 2.0 Bq/L), doses can only be estimated as being less than the dose at that concentration.

(c) Dose is not calculated because there is no pathway to dose to the public.

(d) Plants at these locations are rooted in areas of known subsurface contamination.

The Livermore Valley wines represent vintages from 2001, 2005 and 2006; the California wines represent vintages from 2003 and 2005; and the Rhone Valley wines represent vintages from 2003 and 2004. Tritium concentrations must be decay-corrected to the year of harvest to correlate with tritium concentrations in air and soil to which the grape was exposed. In 2007, decay-corrected concentrations for Livermore Valley wine samples ranged from 0.77 to 2.4 Bq/L; for the two California wine samples, 0.38 and 0.72 Bq/L; and for the two Rhone Valley wine samples, 3.2 and 4.5 Bq/L.

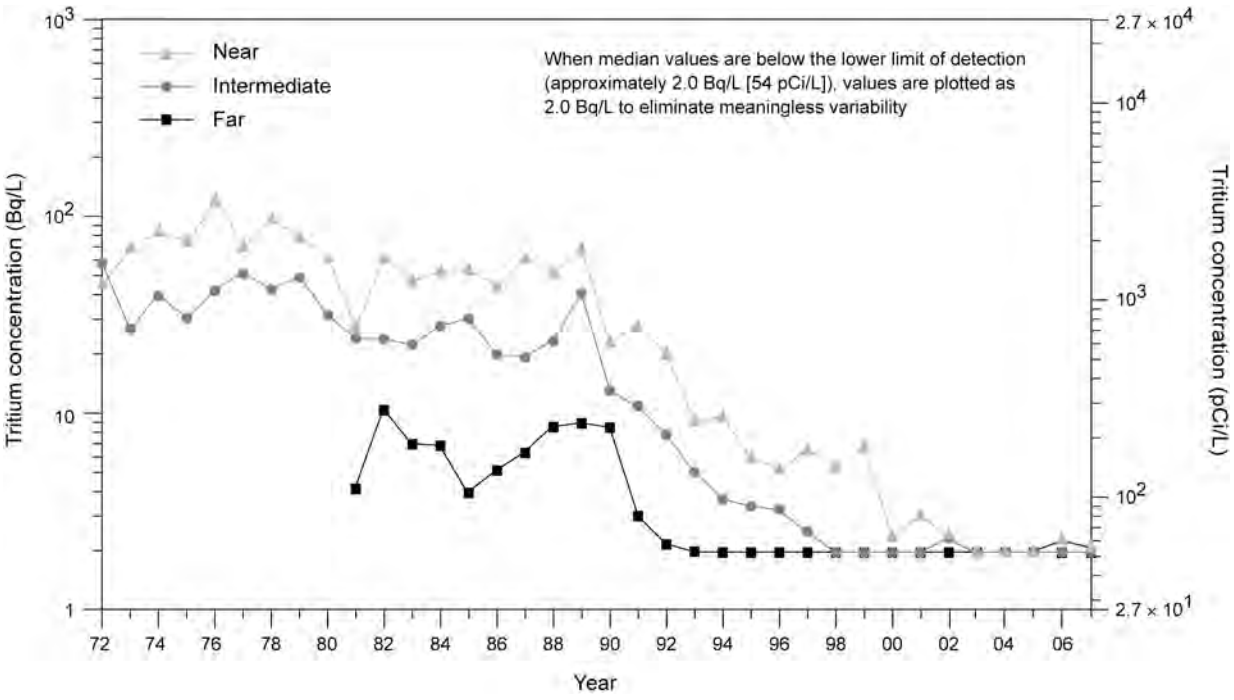

Figure 6-4. Median tritium concentrations in Livermore site and Livermore Valley plant water samples, 1972 to 2007.

Table 6-2. Tritium in retail wine, 2007[a,b]

Sample	Concentration by area of production (Bq/L)		
	Livermore Valley	California	Europe
1	1.9 ± 0.09	0.56 ± 0.08	3.7 ± 0.09
2	0.67 ± 0.08	0.33 ± 0.08	2.5 ± 0.09
3	1.5 ± 0.08		
4	2.0 ± 0.09		
5	1.4 ± 0.08		
6	2.1 ± 0.08		
Dose (nSv/y)[c]	2.6	0.68	4.5

(a) Radioactivities are reported here as the measured concentration and an uncertainty (±2σ counting error).

(b) Wines from a variety of vintages were purchased and analyzed for the 2007 sampling. Concentrations are those measured in March 2008.

(c) Calculated based on consumption of 52 L wine per year at maximum concentration (see **Chapter 7**). Doses account for contribution of OBT as well as of HTO.

6.2.3 Environmental Impact on Vegetation and Wine

6.2.3.1 Vegetation

Hypothetical annual ingestion doses for mean concentrations of tritium in vegetation are shown in **Table 6-1**. These hypothetical doses, from ingestion of HTO in vegetables, milk, and meat, were calculated from annual mean measured concentrations of HTO in vegetation using the transfer factors from **Table 6-3** based on U.S. Nuclear Regulatory Commission Regulatory Guide 1.109 (U.S. NRC 1977). The hypothetical annual ingestion dose, based on the highest observed mean HTO concentration in vegetation for 2007, was 110 nSv (11 µrem).

Table 6-3. Bulk transfer factors used to calculate inhalation and ingestion doses (in µSv) from measured concentrations in air, vegetation, and drinking water

Exposure pathway	Bulk transfer factors[a] times observed mean concentrations
Inhalation and skin absorption	0.21 x concentration in air (Bq/m^3); see **Chapter 4**
Drinking water	0.013 x concentration in drinking water (Bq/L); see **Chapter 5**
Food ingestion	0.0049 x concentration in vegetation (Bq/kg); factor obtained by summing contributions of 0.0011 for vegetables, 0.0011 for meat and 0.0027 for milk

(a) See Sanchez et al. (2003), Appendix C, for the derivation of bulk transfer factors.

Doses calculated based on Regulatory Guide 1.109 neglect the contribution from organically bound tritium (OBT). However, according to a panel of tritium experts, "the dose from OBT that is ingested in food may increase the dose attributed to tritium by not more than a factor of two, and in most cases by a factor much less than this" (ATSDR 2002, p. 27). Thus, the maximum estimated ingestion dose from LLNL operations for 2007, including OBT, is 220 nSv/y (22 µrem/y). This maximum dose is about 1/13,000 of the average annual background dose in the United States from all natural sources and about 1/46 the dose from a panoramic dental x-ray.

Ingestion doses of Site 300 vegetation were not calculated because neither people nor livestock ingest vegetation at Site 300.

6.2.3.2 Wine

For Livermore Valley wines purchased in 2007, the highest concentration of tritium (2.1 Bq/L [57 pCi/L]) was just 0.28% of the EPA's standard for maximal permissible level of tritium in drinking water (740 Bq/L [20,000 pCi/L]). Drinking one liter per day of the Livermore Valley wine with the highest concentration purchased in 2007 would have resulted in a dose of 18 nSv/y (1.8 µrem/y). A more realistic dose estimate, based on moderate drinking (one liter per week)[1] at the mean of the Livermore Valley wine concentrations (1.6 Bq/L [43 pCi/L]) would have been 1.9 nSv/y (0.19 µrem/y). Both doses explicitly account for the added contribution of OBT.[2]

(1) Moderate consumption is higher than the average consumption of wine in California (15.7 L/yr) (Avalos 2005).

(2) Dose from wine was calculated based on the measured concentration of HTO multiplied by 1.3 to account for the potential contribution of OBT that was removed so that the tritium in wine could be counted using liquid scintillation counting. Dose coefficients for HTO and OBT are those of the International Commission on Radiological Protection (1996).

The potential dose from drinking Livermore Valley wines in 2007, including the contribution of OBT, even at the high consumption rate of one liter per day, and the highest observed concentration, would be about 1/740 of a single dose from a panoramic dental x-ray.

6.3 Ambient Radiation Monitoring

LLNL's ambient radiation monitoring program is designed to distinguish between naturally occurring gamma radiation and any ambient radiation field as a direct result of LLNL operations. By sampling at enough locations in the surrounding community, the variance in the natural background from season to season and by location is measured and compared to a five-year trend. The long-term trend analysis allows the radiation field affects from operations to be readily recognized.

In addition to the surveillance monitoring effort for normal operations, a network of real-time sensors was deployed in August of 2001 to monitor for off-normal conditions at the laboratory's perimeter that may occur. A complete discussion of the development and operation of the RTRAM network may be found in the peer reviewed journal article in IEEE Special Issue on Sensors for the Prevention of Terrorist Acts titled "Development of a Real-Time Radiological Area Monitoring Network for Emergency Response at Lawrence Livermore National Laboratory" (Bertoldo 2005).

6.3.1 Methods and Reporting

Exposure to external radiation is measured by correlating the interaction of ionizing energy with its effect on matter that absorbs it. LLNL uses the Panasonic UD-814AS1 TLD, which contains three crystal elements of thallium-activated calcium sulfate ($CaSO_4$), to measure environmental gamma dose representative of external exposure to the public at these sample locations. Comparisons are made for LLNL perimeter locations to those of the Livermore Valley (background location) for the purposes of determining an elevated radiation field. This is similarly done for Site 300 and its nearby locations.

As a TLD absorbs ionizing energy, electron–hole pairs are created in the crystal lattice, trapping this absorbed energy in the crystal's excited state. The absorbed energy released in the form of light emission (glow curve) upon heating is proportional to the TLD absorbed dose which is calibrated to a known standard of cesium-137 gamma energy of 662 keV. The calculated result of the TLD exposure is then reported in the SI unit of Sv from the measured dose in mR.

To compare LLNL dose contributions with the natural background, the analysis is divided into three groups:

- comparison of the average quarterly dose (mSv) for the Livermore site, Livermore Valley, and Site 300 locations for the five-year period from 2002 to 2007
- comparison of the average quarterly dose (mSv) for the Livermore site and Livermore Valley locations in 2007

- comparison of average quarterly dose (mSv) for Site 300, city of Tracy, and Site 300 vicinity in 2007

The results of these comparisons are shown in **Figure 6-5**.

To obtain a true representation of local site exposure and determine any dose contribution from LLNL operations, an annual environmental monitoring compliance assessment is done in accordance with DOE Order 450.1 through a quarterly deployment cycle. TLDs are deployed at a height of 1 m, adhering to regulatory guidance.

For the purpose of reporting comparisons, data are reported as a "standard 90-day quarter" with the dose reported in millisievert (mSv; 1 mSv = 100 mrem).

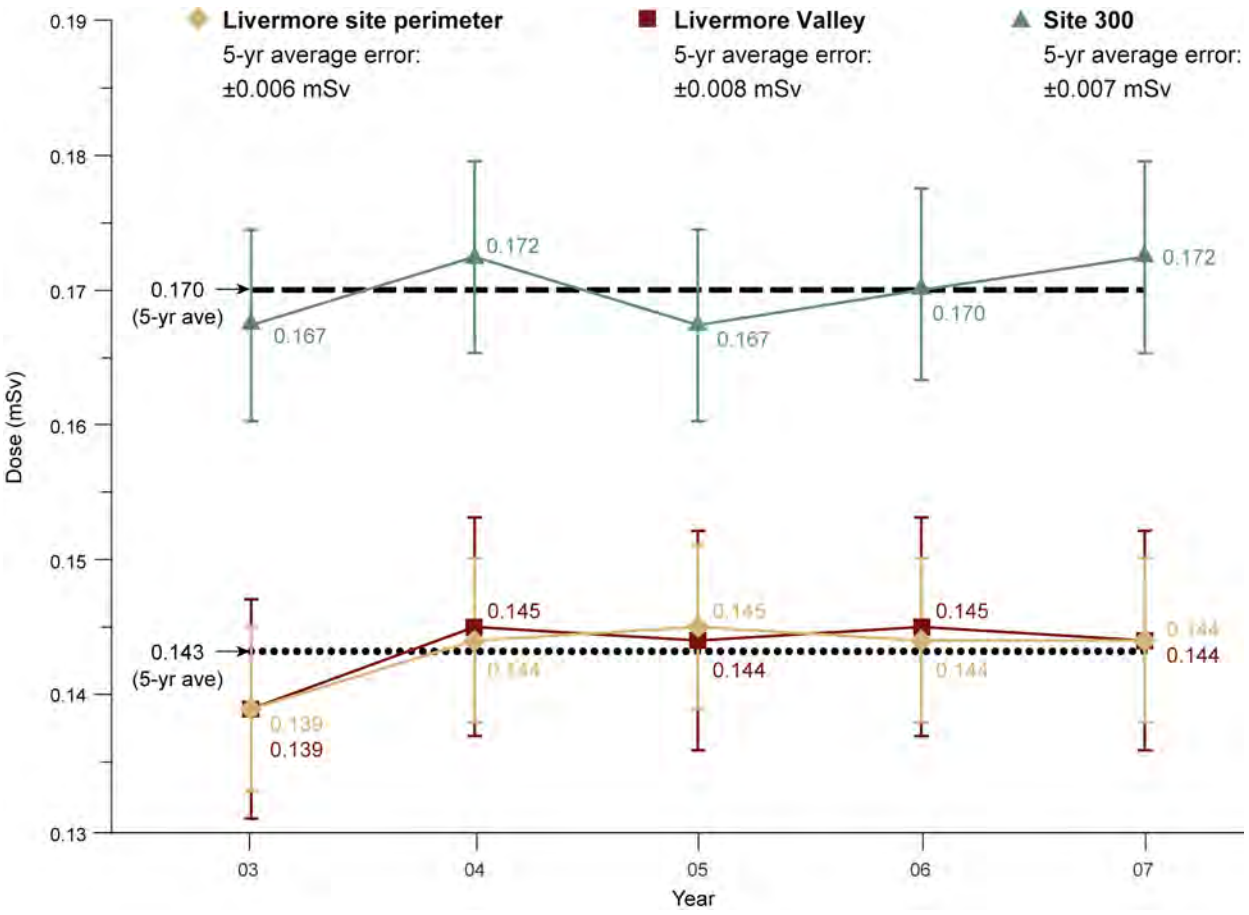

Figure 6-5. Comparison of the average quarterly dose for the Livermore site, Livermore Valley, and Site 300 monitoring locations from 2003 to 2007.

6.3.2 Monitoring Results

Figure 6-5 represents the average quarterly dose (in mSv) for the recent five-year period for the Livermore site perimeter, Livermore Valley and Site 300. Tabular data for each sampling location are provided in **Appendix A**, **Section A.9**.

The difference in the doses at the Livermore site perimeter, Livermore Valley, and Site 300 can be attributed directly to the difference in the geological substrates. The Neroly Formation in the region around Site 300 contains higher levels of naturally occurring thorium that provides the higher external radiation dose.

6.3.3 Environmental Impact from Laboratory Operations

There is no increased ambient radiation field produced as a direct result of LLNL operations for 2007 as measured by this network. Radiation dose trends remain consistent with annual average levels for each sample location and synonymous to natural background levels. As depicted in **Figure 6-5**, the annual average gamma radiation dose for the LLNL site perimeter and the Livermore Valley from 2002 to 2007 are statistically equivalent and show no discernible impact due to operations conducted at LLNL.

6.4 Special Status Wildlife and Plants

Special status wildlife and plant monitoring at LLNL focuses on species considered to be rare, threatened, or endangered (including species listed under the federal or California ESAs; species considered of concern by the California Department of Fish and Game [CDFG] and the USFWS; and species that require inclusion in NEPA and California Environmental Quality Act [CEQA] documents).

Five species that are listed under the federal or California ESAs are known to occur at Site 300—the California tiger salamander (*Ambystoma californiense*), California red-legged frog (*Rana aurora draytonii*), Alameda whipsnake (*Masticophus lateralis euryxanthus)*, valley elderberry longhorn beetle (*Desmocerus californicus dimorphus)*, and the large-flowered fiddleneck (*Amsinckia grandiflor*a). Although there are no recorded observations of the federally endangered San Joaquin kit fox (*Vulpes macrotis mutica*) at Site 300, this species is known to have historically occurred in the adjacent Carnegie and Tracy Hills areas (USFWS 1998). Because of the proximity of known observations of San Joaquin kit fox to Site 300, it is necessary to consider potential impacts to San Joaquin kit fox during activities at Site 300. California threatened Swainson's Hawks (*Buteo swainsoni*) and California-endangered Willow Flycatchers (*Empidonax traillii*) have been observed at Site 300, but breeding habitat for these species does not occur at Site 300. The California red-legged frog is also known to occur at the Livermore site (see **Figure 6-1**).

Known observations of the five listed species and two California species of special concern (Western Burrowing Owl [*Athene cunicularia*] and Tricolored Blackbird [*Agelaius tricolor*]) are shown in **Figures 6-6** and **6-7**. Vertebrate species and rare invertebrate species known to occur at Site 300, including state and federally listed species and other species of special concern are listed in **Appendix C**. A similar list has not been prepared for the Livermore site.

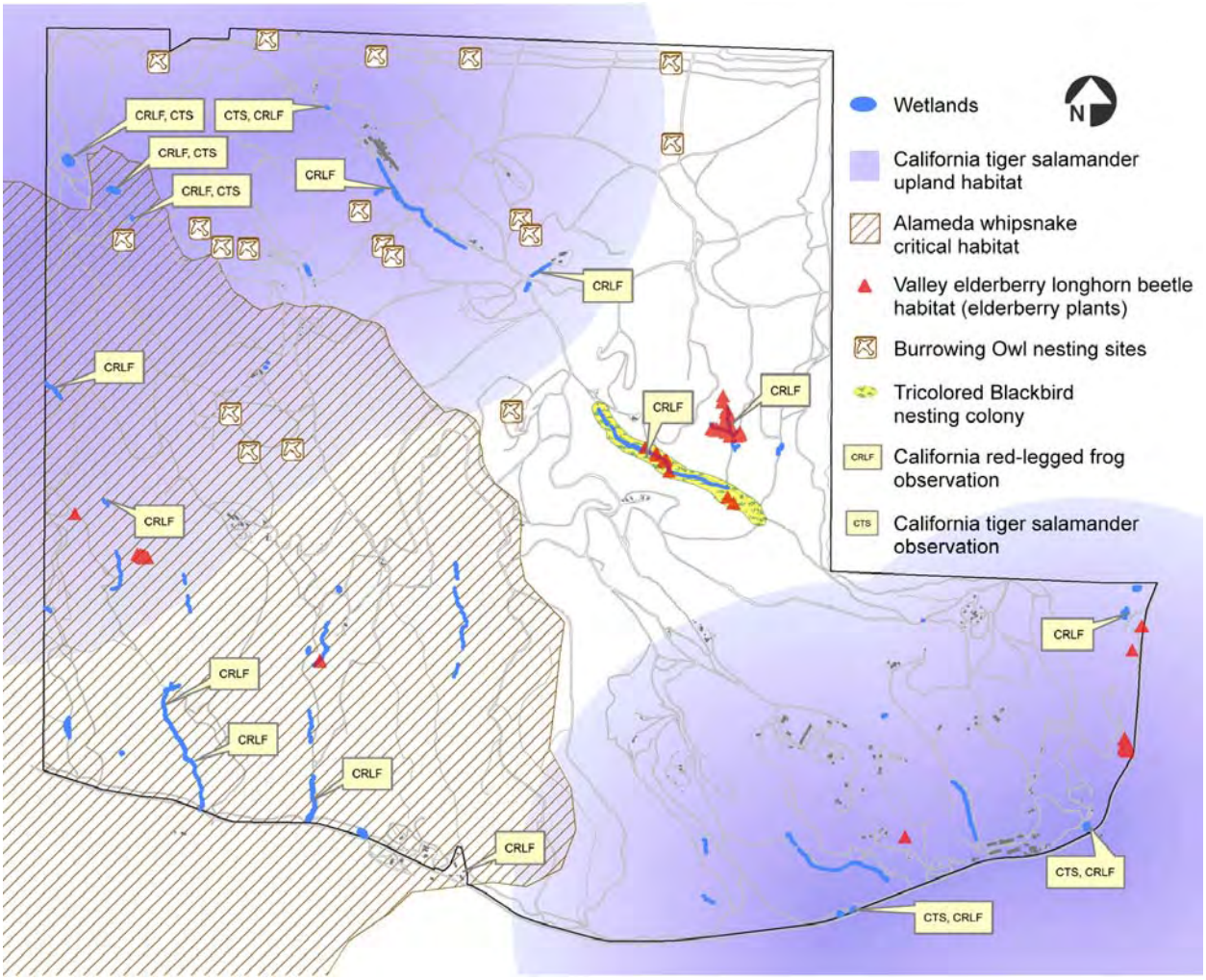

Figure 6-6. Distribution of special status wildlife, Site 300, 2007.

Including the federally endangered large-flowered fiddleneck, four rare plant species and four uncommon plant species are known to occur at Site 300. The four rare species—the large-flowered fiddleneck, the big tarplant (*Blepharizonia plumosa*), the round-leaved filaree *(California macrophylla)*, and the diamond-petaled California poppy (*Eschscholzia rhombipetala*)—are included in the California Native Plant Society (CNPS) List 1B (CNPS 2008). These species are considered rare and endangered throughout their range. The location of these four rare plant species at Site 300 is shown in **Figure 6-7**.

The four uncommon plant species—the gypsum-loving larkspur (*Delphinium gypsophilum* subsp. *gypsophilum*), California androsace (*Androsace elongata* subsp. *acuta*), stinkbells (*Fritillaria agrestis*), and hogwallow starfish (*Hesperevax caulescens*)—are all included on the CNPS List 4 (CNPS 2008). Past surveys have failed to identify any rare plants on the Livermore site (Preston 1997, 2002).

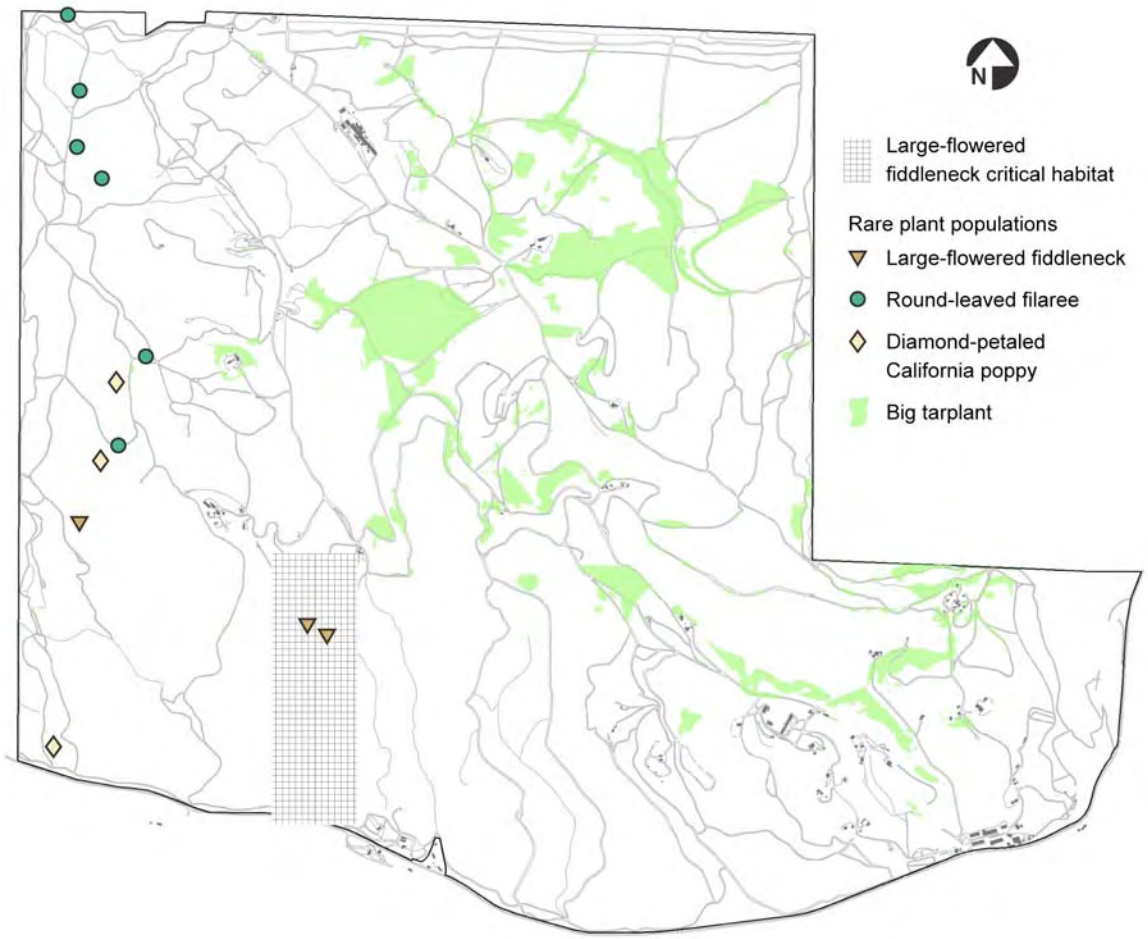

Figure 6-7. Distribution of special status plants, Site 300, 2007.

6.4.1 Compliance Activities

6.4.1.1 Arroyo Seco Restoration

LLNL conducted the second year of the five-year monitoring plan required by USFWS and ACOE for the restoration of the Arroyo Seco Management Plan project site. Monitoring at this site includes annual measurements of the survivorship of plants that were installed as part of the restoration and estimates of the percent cover of grasses and forbs, shrubs, and trees at the project site. Results of this monitoring are documented in Paterson (2008b). In 2007, the percent cover of grasses and forbs was above the expected success criteria for year two in all portions of the project site, although the observed percent cover for shrubs and trees was slightly lower than the success criteria in some portions of the project site. To help correct deviations from the success criteria described above, approximately 135 plants were installed at the site in the winter of 2007/2008 to replace plants that did not survive the previous year, and measures were taken to control weeds at the site.

6.4.1.2 Habitat Enhancement Projects

In late August 2005, LLNL implemented a habitat enhancement project for California red-legged frogs at Site 300 in accordance with a 2002 USFWS BO and ACOE and RWQCB permits. California red-legged frogs were translocated to the new habitat enhancement pools in February and March of 2006. Monitoring demonstrated that California red-legged frogs successfully reproduced in these pools in 2006 and 2007. In 2007, twelve California red-legged frog egg masses were observed in the Upper Mid-Elk Ravine pool and ten egg masses were seen in the lower pool. All egg masses successfully reared larvae. Hundreds of recently metamorphed frogs were counted during fall daytime surveys.

In fall 2005, a depression in the northwest corner of Site 300 below Harrier pool was deepened and expanded to serve as mitigation for California tiger salamander habitat lost as a result of closing two man-made, high explosives rinse water ponds in the Process Area. In 2006, California tiger salamanders successfully bred and metamorphosed from the pool. In 2007, the pool received inadequate inundation and evaporated before the salamander larvae could reach maturity and leave the pond.

6.4.1.3 Oasis and Round Valley Culvert Replacement Projects

In 2006, LLNL completed culvert replacement projects at two Site 300 locations (the Oasis and Round Valley) where unpaved fire trails crossed intermittent drainages. The Round Valley project included the creation of a pool upstream of the project area in part as mitigation for the impacts at the Oasis site and to serve as enhanced habitat for amphibian species. These projects were completed under the USFWS BO for maintenance and operations of Site 300 and ACOE and RWQCB permits. Although the Oasis site no longer contains habitat for breeding California red-legged frogs, one egg mass was found between rip-rap boulders. It did not successfully hatch to produce larvae. The 2006/2007 rainy season was drier than average, and the Round Valley pool did not receive enough water during the 2006/2007 winter to pool and afford potential breeding habitat for amphibians.

6.4.1.4 Pit 7 Remediation

In accordance with the requirements of the NEPA and CEQA documents for the Environmental Remediation of the Site 300 Pit 7 Complex, and the USFWS BO for maintenance and operations of Site 300, pre-construction rare plant surveys and wildlife surveys were conducted at the Pit 7 Remediation site in 2007.

Several small populations of the California androsace were found in rock outcroppings near the project site. Two Western Burrowing Owl nests were also discovered near the construction site, but these were not impacted, as construction did not start until October 2007 after Burrowing Owls had fledged. Buffer zones were established around these rare plants during construction to avoid impacting this species. Ongoing biological surveys conducted during construction ensured that any species discovered in the area received adequate protection. During construction, two California tiger salamanders were relocated from within the project site.

6.4.1.5 Arroyo Mocho Boulder Removal Project

A pumping plant, which draws water from the Hetch Hetchy aqueduct, is the primary source of water for LLNL's Livermore site. Several large boulders fell into the channel of Arroyo Mocho below the pumping plant, potentially forcing the flow of the arroyo toward the hillside that the pumping plant is located on and resulting in an erosion hazard to this hillside and the pumping plant.

Arroyo Mocho and the surrounding area are habitat to California red-legged frog, California tiger salamander, and Alameda whipsnake. In 2007, two of these boulders were removed from Arroyo Mocho to mitigate erosion hazards. This work was conducted under an amendment to the 2004 BO for the Arroyo Mocho Road Improvement and Anadromous Fish Passage project. LLNL wildlife biologists monitored all in-channel work. No listed species were observed at the project site during boulder removal, and no impacts to special status species resulted from this project.

6.4.1.6 Arroyo Mocho Restoration

In 2007, LLNL implemented the third year of a five-year mitigation and monitoring plan for the restoration of the 2004 Arroyo Mocho Road Improvement and Anadromous Fish Passage project. This mitigation and monitoring plan is a requirement by the ACOE permit for this project. Success criteria for this restoration are based on the number of native species present and the percent cover of these species within three monitoring communities (low flood plain, sloping terrace and upland) at the project site. In 2006 and 2007, the number of native species and the percent cover of these species were above the success criteria with one exception. In 2007, the average percent cover of native plants was 44% in the sloping terrace community compared to the success criterion of 45%.

In an attempt to control exotic plants, as specified in the mitigation and monitoring plan, and increase the cover of native plants at the site, hand weeding of exotic species including yellow star thistle and bull thistle was conducted in 2007.

The mitigation and monitoring plan for this project also requires the replacement of container plants that do not survive the first two years following construction. To meet this requirement, container plants were installed in January of 2007 and acorns were planted in December of 2007. The results of the monitoring are documented in Paterson (2008a).

6.4.2 Invasive Species Control Activities

Invasive species control is an important part of LLNL's effort to protect special status species at both sites. Prevention of the downstream dissemination of invasive species is also important to protect native species throughout our region. The bullfrog *(Rana catesbeiana)* and the largemouth bass *(Micropterus salmoides)* are significant threats to California red-legged frogs at the Livermore site, and the feral pig (*Sus scrofa*) threatens California red-legged frog habitat at Site 300.

In 2007, to mitigate threats to California red-legged frogs, six feral pigs were dispatched at Site 300. At the Livermore site, bullfrog control measures were implemented between May and September of 2007. Bullfrog control measures included dispatching adults and removing egg masses in Lake Haussmann and Arroyo Las Positas. To remove bullfrog tadpoles and invasive fish, the LLNL reach of Arroyo Las Positas was allowed to dry out in October of 2007 by temporarily halting groundwater discharges to the arroyo.

6.4.3 Surveillance Monitoring

6.4.3.1 Wildlife Monitoring and Research

Alameda Whipsnake. Since 2002, LLNL has participated in a study, in cooperation with the USFWS and four other agencies, to determine the effects of prescribed burns on the Alameda whipsnake. The USFWS issued a BO for this study that outlined the general conditions for conducting prescribed burns and gathering information about potential impacts to Alameda whipsnakes. Participation in this study allowed LLNL to obtain USFWS approval to conduct prescribed burns necessary for Site 300 operations in areas that support Alameda whipsnakes. Previous LLNL Environmental Reports document the study area and baseline conditions, and early results.

A prescribed burn was conducted at the burn site in the summer of 2003, and the post-burn monitoring has been conducted from the fall of 2003 through 2007. Both the burn and control sites were impacted by a wildfire in 2005. Although no whipsnake fatalities were documented during post-burn surveys, both trapping areas were burned severely and little remnant vegetation was left in the shrubland.

No whipsnakes were captured during the spring 2007 trapping period. Although the effects of the prescribed burn and subsequent impacts of the wildfire on the whipsnake are not yet determined, both the whipsnake and its habitat are adapted to periodic fire events and both the snake and vegetation are expected to recover from the fire in subsequent years.

Nesting Bird Surveys. LLNL conducts nesting bird surveys to ensure LLNL activities comply with the Migratory Bird Treaty Act and do not result in impacts to nesting birds. White-tailed Kites annually nest in the trees along the north, east, and south perimeter of the Livermore site. LLNL staff surveyed potential White-tailed Kite nesting sites during the spring of 2007; two pairs of White-tailed Kites successfully fledged young. Although White-tailed Kites are also known to occasionally nest at Site 300, site-wide kite surveys were not conducted at Site 300 in 2007 because kites do not typically nest in areas where they may be affected by programmatic activities.

Avian Monitoring Program. In 2007, LLNL continued its avian monitoring program, which was initiated in 2001. A constant effort mist netting station was established spanning Elk Ravine and Gooseberry Canyon at Site 300. Birds were captured using ten standard passerine mist nets once every ten days throughout the breeding season (May through August). Captured birds were identified to species, banded, aged, sexed, measured, and weighed before being released. All of

the species identified in these surveys are listed in **Appendix C**. Data from this program is contributed to the national Monitoring Avian Productivity and Survivorship (MAPS) program, which is operated by the Institute for Bird Population.

California Red-Legged Frog Egg Mass Surveys. LLNL continued diurnal visual surveys for California red-legged frog egg mass at the Livermore site in Arroyo Las Positas and in the habitat enhancement portion of Lake Haussmann. A total of two egg masses were observed in Arroyo Las Positas in 2007. This is down from a maximum of 37 egg masses observed in 2001. Three egg masses were observed in the Habitat Enhancement portion of Lake Haussmann in 2007.

6.4.3.2 Rare Plant Research and Monitoring

Large-Flowered Fiddleneck. This species is known to exist naturally in only two locations—at the Site 300 Drop Tower and on a nearby ranch. The Drop Tower native population contained only one large-flowered fiddleneck plant in 2007, and fewer than 20 plants each year for the past five years.

LLNL established an experimental population of the large-flowered fiddleneck at Site 300 beginning in the early 1990s. The size of the experimental population fluctuates as a result of seed bank enhancement efforts conducted in this population. The two experimental subpopulations combined contained 109 large-flowered fiddleneck plants in 2007.

Big Tarplant. The distribution of big tarplant was mapped at Site 300 using a handheld global positioning system (GPS) in September and October of 2007. This species is abundant at Site 300, especially in or near areas where prescribed burned are routinely conducted, although it is rare outside of Site 300. It is estimated that between 55,000 and 145,000 individual big tarplants occurred at Site 300 in 2007.

Diamond-Petaled California Poppy. Currently three populations of this species are known to occur at Site 300; the population locations are referred to as Site 1, Site 2, and Site 3. Although the species is not listed under the federal or California ESAs, it is extremely rare and is currently known to occur only at Site 300 and in one location in San Luis Obispo County. A census of the three Site 300 populations was conducted in March and April 2007. In 2007, a total of 99 plants were found at Site 300. The most recently discovered population, Site 3, contained by far the largest number (86 plants). Numbers of plants at Sites 1 and 2 have been very small in recent years. In 2007, Site 1 had 7 plants, and Site 2 had 6 plants.

Round-Leaved Filaree. Six populations of round-leaved filaree are known to occur at Site 300. All populations occur in the northwest portion of the site. This species thrives in the disturbed soils of the annually graded fire trails at Site 300. Of the six populations, four occur on fire trails. During the spring of 2007, the extent of the six populations was mapped using a handheld GPS, and the size of each population was estimated. The six populations combined were estimated to contain over 1150 plants.

6.4.4 Environmental Impacts on Special Status Wildlife and Plants

Through monitoring and compliance activities in 2007, LLNL has been able to avoid impacts to special status wildlife and plants. In addition, LLNL continues to monitor and maintain several restoration sites and habitat enhancements that are beneficial to native plants and animals at the Livermore site and Site 300. Invasive species continue to be one of the largest threats to California red-legged frogs at the Livermore site and Site 300, and LLNL continued its program to remove invasive exotic species of amphibians and fish from the Livermore site, and feral pigs from Site 300 in 2007.

7. Radiological Dose Assessment

Jennifer Larson, Gretchen M. Gallegos

Lawrence Livermore National Laboratory assesses potential radiological doses to biota, off-site individuals, and the population residing within 80 km of either of the two LLNL sites, the Livermore site and Site 300. These potential doses are calculated to determine the impact of LLNL operations, if any, on the general public and the environment, and to demonstrate compliance with regulatory standards set by the U.S. DOE and the U.S. EPA. For protection of the public, DOE has set the limit for prolonged exposure of a maximally exposed individual in an uncontrolled area at 1 mSv/y whole-body effective dose equivalent (EDE), which equals 100 mrem/y EDE. For occasional exposure, the limit is 5 mSv/y (500 mrem/y) EDE. EDEs and other technical terms are defined in the glossary and discussed in "Supplementary Topics on Radiological Dose" (see **Appendix D** or Sanchez [2003], Appendix D).

The release of radioactive material to air is the major source of public radiological exposure from LLNL operations. Therefore, LLNL expends a significant effort monitoring stack air effluent for radiological releases and ambient air for radiological impact due to LLNL operations.

Measurements of radiological releases to air and modeling the dispersion of the released radionuclides are used to determine LLNL's dose to the public. Because LLNL is a DOE facility, it is subject to the requirements of 40 CFR Part 61, Subpart H of the NESHAPs. The EPA's radiation dose standard for members of the public limits the EDE to 100 μSv/y (10 mrem/y) for air emissions. LLNL uses the EPA CAP88-PC computer model to help demonstrate site compliance with NESHAPs regulations. CAP88-PC is used to evaluate the four principal exposure pathways: ingestion, inhalation, air immersion, and irradiation by contaminated ground surface. The relative significance of inhalation and ingestion depends on the assumptions made about the origin of food consumed and the predominant radionuclide contributing to dose.

The major radionuclides measured by LLNL in 2007 that contributed to individual and collective dose were tritium at the Livermore site and three uranium isotopes (uranium-234, uranium-235, and uranium-238) at Site 300. All radionuclides measured at the Livermore site and Site 300 were used to assess dose to biota.

This chapter summarizes detailed radiological dose determinations and identifies trends over time while placing them in perspective with natural background and other sources of radiation exposure.

7.1 Air Dispersion and Dose Models

Computational models are needed to describe the transport and dispersion in air of contaminants and the doses to exposed persons via all pathways. CAP88-PC is the EPA-mandated computer model used by LLNL to compute radiological individual or collective (i.e., population) dose

resulting from radionuclide emissions to air. A site-specific wind parameter file is prepared annually from meteorological data collected by LLNL. The mathematical models and equations used in CAP88-PC are described by Parks (1992).

7.2 Identification of Key Receptors

Dose is assessed for two types of receptors. First is the dose to the site-wide maximally exposed individual (SW-MEI; defined below) member of the public. Second is the collective or "population" dose received by people residing within 80 km of either of the two LLNL sites.

The SW-MEI is defined as the hypothetical member of the public at a single, publicly accessible location who receives the greatest LLNL-induced EDE from all sources at a site. For LLNL to comply with NESHAPs regulations, the LLNL SW-MEI must not receive an EDE equal to or greater than 100 μSv/y (10 mrem/y) from releases of radioactive material to air. Public facilities that could be the location of the SW-MEI include schools, churches, businesses, and residences. This hypothetical person is assumed to remain at one location 24 hours per day, 365 days per year, continuously breathing air having the predicted or observed radionuclide concentration, and consuming a specified fraction of food and drinking water(1) that is affected by the same predicted or observed air concentration caused by releases of radioactivity from the site. Thus, the SW-MEI dose is not received by any actual individual and is a conservative estimate of the highest possible dose that might be received by any member of the public.

In 2007, the SW-MEI at the Livermore site was located at the UNCLE Credit Union, about 10 m outside the site's controlled eastern perimeter, and 957 m east-northeast of the Tritium Facility. The SW-MEI at Site 300 was located on the site's south-central perimeter, which borders the Carnegie State Vehicular Recreation Area. The location was 3170 m south–southeast of the firing table at Building 851. The two SW−MEI locations are shown in **Figure 7-1**.

7.3 Results of 2007 Radiological Dose Assessment

This section summarizes the doses to the most exposed public individuals from LLNL operations in 2007, shows the temporal trends compared with previous years, presents the potential doses to the populations residing within 80 km of either the Livermore site or Site 300, and places the potential doses from LLNL operations in perspective with doses from other sources.

7.3.1 Total Dose to Site-Wide Maximally Exposed Individuals

The total dose to the SW-MEI from Livermore site operations in 2007 was 0.031 μSv/y (0.0031 mrem/y). Of this, the dose attributed to diffuse emissions (area sources) totaled 0.018 μSv (0.0018 mrem) or 58%; the dose due to point sources was 0.013 μSv 0.0013 mrem) or 42% of the total. The point source dose includes Tritium Facility elemental tritium gas (HT) emissions modeled as tritiated water (HTO), as directed by EPA Region IX.

(1) Calculated for tritium only.

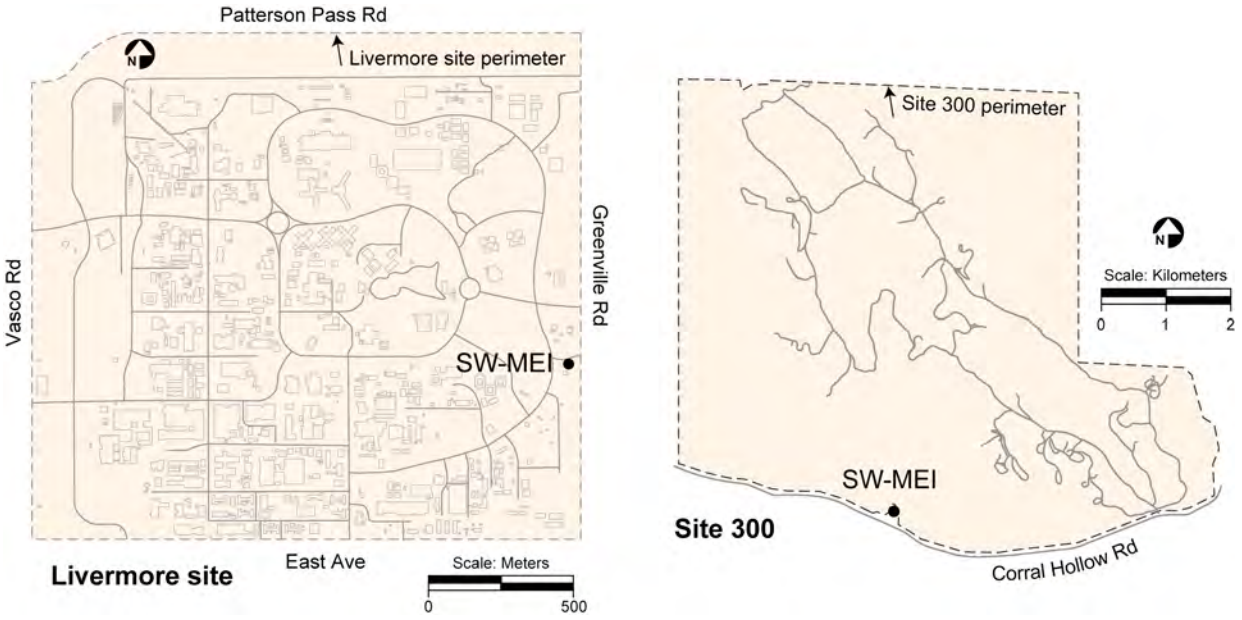

Figure 7-1. Location of the SW-MEI at the Livermore site and Site 300, 2007.

The total dose to the Site 300 SW-MEI from operations in 2007 was 0.035 µSv (0.0035 mrem). Point source emissions from firing table explosives experiments totaled 0.031 µSv (0.0031 mrem) accounting for 90% of the dose, while 0.004 µSv (0.0004 mrem), or about 10%, was contributed by diffuse emission sources.

Table 7-1 shows the facilities or sources that accounted for nearly 100% of the dose to the SW-MEI for the Livermore site and Site 300 in 2007. Although LLNL has nearly 150 sources with the potential to release radioactive material to air according to NESHAPs prescriptions, most are very minor. Nearly the entire radiological dose to the public in 2007 from LLNL operations came from no more than six sources. LLNL uses, with permission from EPA, surveillance monitoring in place of inventory-based modeling to account for dose contributions from the numerous minor sources.

Dominant radionuclides at the two sites were the same as in recent years. Tritium accounted for about 86% of the Livermore site's calculated dose. At Site 300, practically the entire calculated dose was due to the isotopes uranium-238, uranium-235, and uranium-234 from depleted uranium. Regarding pathways of exposure, for individual doses calculated for tritium, the ingestion dose accounts for slightly more than the inhalation dose, approximately 53% and 47%, respectively. For uranium, the inhalation pathway dominates: 97% by the inhalation pathway versus 3% via ingestion. Air immersion and ground irradiation pathways are negligible for both tritium and uranium.

Table 7-1. List of facilities or sources whose combined emissions accounted for nearly 100% of the SW-MEI doses for the Livermore site and Site 300 in 2007.

Site	Facility (source category)	CAP88-PC dose (µSv/y)[a]	CAP88-PC contribution to total dose
Livermore site	Tritium Facility stacks (point source)	0.013	42%
	Building 612 yard (diffuse source)	0.010	32%
	Southeast quadrant soil resuspension (diffuse source)	0.0040	13%
	Tritium Facility outside (diffuse source)	0.0040	13%
Site 300	Building 851 firing table (point source)	0.031	90%
	Soil resuspension (diffuse source)	0.0035	10%

(a) 1 µSv = 0.1 mrem

The doses to the SW-MEI from emissions at the Livermore site and Site 300 since NESHAPs reporting began are shown in **Table 7-2**. These SW-MEI dose estimates are conservative, predicting potential doses that are higher than actually would be experienced by any member of the public, and are all less than 10% of the federal standard of 100 µSv/y.

7.3.2 Doses from Unplanned Releases

There were no unplanned atmospheric releases of radionuclides at the Livermore site or Site 300 in 2007.

7.3.3 Collective Dose

Collective dose for both LLNL sites was calculated using CAP88-PC for a radius of 80 km from the site centers. Population centers affected by LLNL emissions within the 80-km radius include the nearby communities of Livermore and Tracy; the more distant metropolitan areas of Oakland, San Francisco, and San Jose; and the San Joaquin Valley communities of Modesto and Stockton. Within the 80-km radius specified by DOE, there are 7.1 million residents included for the Livermore site collective dose determination and 6.2 million for Site 300. The source of the geographic population distribution data used for this report is Dobson et al. (2000).

The CAP88-PC result for potential collective dose attributed to 2007 Livermore site operations was 0.0050 person-Sv (0.50 person-rem); the corresponding collective dose from Site 300 operations was 0.0028 person-Sv (0.28 person-rem).

Although collective doses from LLNL operations are tiny compared with doses from natural background radiation, they may be high compared with other DOE facilities due to large populations within 80 km of the LLNL sites. However, a large dose to a small number of people is not equivalent to a small dose to many people, even though the collective dose may be the same. Given that the population centers potentially affected by LLNL operations are distant from both the Livermore site and Site 300, the collective doses from LLNL operations are better described by breaking them down into categories of dose received by individuals in the

population affected. The breakdown (or disaggregation) of collective dose by the level of the individual dose is shown in **Table 7-3**.

Table 7-2. Doses calculated for the SW-MEI for the Livermore site and Site 300, 1990 to 2007.

Site	Year	Total Dose (μSv/y)[a]	Site	Year	Total Dose (μSv/y)[a]
Livermore site	2007	0.031	Site 300	2007	0.035
	2006	0.045		2006	0.16
	2005	0.065		2005	0.18
	2004	0.079		2004	0.26
	2003	0.44		2003	0.17
	2002	0.23		2002	0.21
	2001	0.17		2001	0.54
	2000	0.38		2000	0.19
	1999	1.2		1999	0.35
	1998	0.55		1998	0.24
	1997	0.97		1997	0.20
	1996	0.93		1996	0.33
	1995	0.41		1995	0.23
	1994	0.65		1994	0.81
	1993	0.66		1993	0.37
	1992	0.79		1992	0.21
	1991	2.34		1991	0.44
	1990	2.40		1990	0.57

(a) 1 μSv = 0.1 mrem

7.3.4 Doses to the Public Placed in Perspective

As a frame of reference to gauge the size of the LLNL doses, **Table 7-4** compares them to average doses received in the United States from exposure to natural background radiation and other sources. These values vary with location. Collective doses from LLNL operations in 2007 are more than 100,000 times smaller than ones from natural background radiation. The estimated maximum potential doses to individual members of the public from operations at either of the two LLNL sites in 2007 are more than 10,000 times smaller than ones received from background radiation in the natural environment.

Table 7-3. Collective dose broken down by level of individual doses, 2007.

Site	Individual dose range (μSv/y)[a]		Collective dose (person-Sv/y)[b]	Percent total collective dose
Livermore site	0.01 to 0.1		0.000016	<1
	0.001 to 0.01		0.00029	6
	0.0001 to 0.001		0.0047	94
		Total	0.0050[c]	100
Site 300[d]	0.01 to 0.1		0.000055	2
	0.001 to 0.01		0.00097	35
	0.0001 to 0.001		0.00175	63
		Total	0.0028	100

(a) 1 μSv = 0.1 mrem

(b) 1 person-Sv = 100 person-rem

(c) Collective dose output from CAP88-PC for each sector and each distance from the source is in two significant figures. When dose is calculated by summing outputs for each sector and distance, as is done for the disaggregation of collective dose, the total collective dose may be slightly different from the total calculated directly by CAP88-PC.

(d) Dose from Building 851 firing table.

Table 7-4. Comparison of radiation doses from LLNL sources to average doses from background (natural and man-made) radiation, 2007.

Location/source	Category	Individual dose[a] (μSv)[c]	Collective dose[b] (person-Sv)[d]
LLNL			
Livermore site sources	Atmospheric emissions	0.031	0.0050
Site 300 sources	Atmospheric emissions	0.035	0.0028
Other sources[e] (background)	Natural radioactivity[f,g]		
	Cosmic radiation	300	2,130
	Terrestrial radiation	300	2,130
	Internal (food and water consumption)	400	2,840
	Radon	2,000	14,200
	Medical radiation (diagnostic procedures)[f]	530	3,760
	Weapons test fallout[f]	10	71
	Nuclear fuel cycle	4	28

(a) For LLNL sources, this dose represents that experienced by the SW-MEI.

(b) The collective dose is the combined dose for all individuals residing within an 80-km radius of LLNL (approximately 7.1 million people for the Livermore site and 6.2 million for Site 300), calculated with respect to distance and direction from each site. The Livermore site population estimate of 7.1 million people was used to calculate the collective doses for "Other sources."

(c) 1 μSv = 0.1 mrem

(d) 1 person-Sv = 100 person-rem

(e) From National Council on Radiation Protection and Measurements (NCRP 1987a,b)

(f) These values vary with location.

(g) This dose is an average over the U.S. population.

7.4 Special Topics on Dose Assessment

7.4.1 Compliance Demonstration for Minor Sources

From 1991 through 2002, LLNL demonstrated compliance for minor sources of radiation through a labor-intensive inventory and modeling process. The dose consequences to the public for these sources were 8 to 20 orders of magnitude below the regulatory standard of 100 μSv/y (10 mrem/y) and did not justify the level of effort expended in accounting for them. To better allocate resources, in March 2003 LLNL made a request to EPA, pursuant to the NESHAPs regulations, to use existing ambient air monitoring to demonstrate compliance for minor sources. The request was granted by EPA in April 2003, and LLNL began implementation of the approved process with calendar year 2003 data. LLNL demonstrates NESHAPs compliance for minor sources by comparing measured ambient air concentrations at the location of the SW-MEI to concentration limits set by the EPA in 40 CFR Part 61, Table 2, Appendix E. The radionuclides for which the comparison is made are tritium and plutonium-239+240 for the Livermore site SW-MEI and uranium-238 for the Site 300 SW-MEI. At the Livermore site, the average of the monitoring results for locations VIS and CRED represents the SW-MEI. At Site 300, the minor source that has the potential to have a measurable effect is the resuspension of depleted uranium contaminated soil. Because this is a diffuse source, the average of the results for all monitoring locations at the site is used to represent the SW-MEI.

The standards contained in 40 CFR Part 61, Table 2, Appendix E, and the measured concentrations at the SW-MEI are presented in SI units in **Table 7-5**. As demonstrated by the calculation of the fraction of the standard, LLNL-measured air concentrations for tritium and plutonium-239+240 and uranium-238 are less than one–one-hundredth of the health protective standard for these radionuclides.

Table 7-5. Mean concentrations of radionuclides of concern at the location of the SW-MEI in 2007.

Location	Nuclide	EPA concentration standard (Bq/m^3)	Detection limit (approximate) (Bq/m^3)	Mean measured concentration (Bq/m^3)	Measured concentration as a fraction of the standard
Livermore SW-MEI	Tritium	56	0.037	0.036[(a)]	6.4×10^{-4}
Livermore SW-MEI	Plutonium-239	7.4×10^{-5}	1.9×10^{-8}	5.9×10^{-9}[(b)]	8.0×10^{-5}
Site 300 SW-MEI	Uranium-238	3.1×10^{-4}	1.1×10^{-9}	3.5×10^{-7}[(c)]	1.1×10^{-3}

Note: 1 Bq = 2.7×10^{-11} Ci

(a) The tritium value includes contributions from the Tritium Facility, Building 612 yard, Tritium Facility outside yard, and contributions from other minor sources. The mean measured concentration for tritium is less than the approximate detection limit; nonetheless, 50 of the 56 values composing the mean were measured detections.

(b) The mean measured concentration for plutonium is less than the detection limit; only 3 of the 15 values composing the mean were measured detections. Only values greater than zero are used in the calculation of the mean.

(c) The ratio for the mean uranium-235 and uranium-238 concentrations for 2007 is 0.0071, which is less than 0.00725, the ratio of these isotopes for naturally occurring uranium. This results in approximately 97% of the resuspension being attributable to naturally occurring uranium and 3% being attributable to depleted uranium.

7.4.2 Estimate of Dose to Biota

Biota (flora and fauna) also need to be protected from potential radiological exposure from LLNL operations since their exposure pathways are unique to their environment (e.g., a ground squirrel may be exposed to dose by burrowing in contaminated soil). Thus, LLNL calculates potential dose to biota from LLNL operations according to *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (U.S. DOE 2002) and by using the RESRAD-BIOTA computer code, a tool for implementing DOE's graded approach to biota dose evaluation.

Limits on absorbed dose to biota are 10 mGy/d (1 rad/d) for aquatic animals and terrestrial plants, and 1 mGy/d (0.1 rad/d) for terrestrial animals. At LLNL in 2007, radionuclides contributing to dose to biota were americium-241, cesium−137, tritium, plutonium-238, plutonium-239, thorium-232, uranium-234, uranium−235, and uranium-238. In the 2007 LLNL assessment, the maximum concentration of each radionuclide measured in soils, sediments, and surface waters was used in the dose screening calculations; the maximum concentration may have occurred on the Livermore site, in the Livermore Valley, or on Site 300. This approach resulted in an assessment that was unrealistically conservative, given that the maximum concentrations in the media are scattered over a very large area, and no plant or animal could possibly be exposed to them all. Furthermore, although biota would most likely live in and near permanent bodies of water (i.e., surface water), measurements of storm water runoff were used for the assessment because higher concentrations of radionuclides are measured in runoff than in surface waters.

In the RESRAD-BIOTA code, each radionuclide in each medium (i.e., soil, sediment, and surface water) is assigned a Biota Concentration Guide (BCG). Radionuclide concentrations in each medium are divided by the BCG, and the resulting fractions for each nuclide and medium are summed. For aquatic and riparian animals, the sum of the fractions for water exposure is added to the sum of the fractions for sediment exposure. Similarly, fractions for water and soil exposures are summed for terrestrial animals. If the sums of the fractions for the aquatic and terrestrial systems are both less than 1 (i.e., the dose to the biota does not exceed the screening limit), the site has passed the screening analysis and biota are assumed to be protected. In 2007, the sum of the fractions for the aquatic system was 0.032, and the sum for the terrestrial system was 0.043. These results are similar to those for previous years.

7.5 Environmental Impact

The annual radiological doses from all emissions at the Livermore site and Site 300 in 2007 were found to be well below the applicable standards for radiation protection of the public, in particular the NESHAPs standard. This standard limits to 100 μSv/y (10 mrem/y) the EDE to any member of the public arising as a result of releases of radioactive material to air from DOE facilities. Using an EPA-mandated computer model and actual LLNL meteorology appropriate to the two sites, potential doses to the LLNL SW-MEI members of the public from LLNL operations in 2007 were:

- Livermore site: 0.031 μSv (0.0031 mrem)—42% from point-source emissions; 58% from diffuse-source emissions.
- Site 300: 0.035 μSv (0.0035 mrem)—90% from explosive experiments, which are classified as point-sources; 10% from diffuse-source emissions.

As noted earlier, the major radionuclides accounting for the doses were tritium at the Livermore site and the three isotopes of depleted uranium (uranium-234, uranium-235, and uranium-238) at Site 300. The only significant exposure pathway contributing to dose from LLNL operations was release of radioactive material to air, leading to doses by inhalation and ingestion.

The collective EDE attributable to LLNL operations in 2007 was estimated to be 0.0050 person-Sv (0.50 person-rem) for the Livermore site and 0.0028 person-Sv (0.28 person-rem) for Site 300. These doses include potentially exposed populations of 7.1 million people for the Livermore site and 6.2 million people for Site 300 living within a distance of 80 km from the site centers.

The doses to the SW-MEI, which represent the maximum doses that could be received by members of the public resulting from Livermore site and Site 300 operations in 2007, both were less than 1% of the federal standard and were more than 10,000 times smaller than the dose from background radiation. The collective doses from LLNL operations in 2007 were more than 100,000 times smaller than those caused by natural radioactivity in the environment.

Potential doses to aquatic and terrestrial biota from LLNL operations were assessed and found to be well below DOE screening dose limits.

Potential radiological doses from LLNL operations were well below regulatory standards and were very small compared with doses normally received from natural background radiation sources, even though highly conservative assumptions were used in the determination of LLNL doses. The potential maximum doses to the public indicate that LLNL's use of radionuclides had no credible impact on public health during 2007.

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8. Groundwater Investigation and Remediation

Lindee L. Berg, Leslie S. Ferry

During 2007, groundwater investigations and remediations under CERCLA continued at both the Livermore site and Site 300. Lawrence Livermore National Laboratory samples and analyzes groundwater from areas of known or suspected contamination. Portions of the two sites where soil or groundwater contains or may contain chemicals of concern are actively investigated to define the hydrogeology and nature and extent of the contamination and its source. Where necessary, remediation strategies are developed and evaluated in preparation for a CERCLA removal action or through the feasibility study process. An approved remedy for each area is developed in consultation with the regulatory agencies and the community.

This chapter reviews the distribution of contaminants in groundwater and the progress LLNL has made in removing contaminants from groundwater and from the unsaturated zone (soil vapor) at the Livermore site and Site 300. The sites are similar in that the contamination is, for the most part, confined to on site. The sites differ in that Site 300, with an area of 28.3 km^2 (10.9 mi^2), is much larger than the Livermore site and has been divided into eight operable units (OUs) based on the nature and extent of contamination, and topographic and hydrologic considerations. The Livermore site at 3.3 km^2 (1.3 mi^2) is effectively one OU.

8.1 Livermore Site Ground Water Project

Initial releases of hazardous materials occurred at the Livermore site in the mid-to-late 1940s during operations at the Livermore Naval Air Station (Thorpe et al. 1990). There is also evidence that localized spills, leaking tanks and impoundments, and landfills contributed VOCs, fuel hydrocarbons, metals, and tritium to the unsaturated zone and groundwater in the post-Navy era. The Livermore site was placed on the U.S. Environmental Protection Agency National Priorities List in 1987.

An analysis of all environmental media showed that groundwater and both saturated and unsaturated soils are the only media that require remediation (Thorpe et al. 1990). Compounds that currently exist in groundwater at various locations beneath the site at concentrations above drinking water standards (MCLs) are TCE, PCE, 1,1-dichloroethylene, chloroform, 1,2-dichloroethylene, 1,1-dichloroethane, 1,2-dichloroethane, trichlorotrifluoroethane (Freon-113), trichlorofluoromethane (Freon-11), and carbon tetrachloride. PCE is also present at low concentrations slightly above the MCL in off-site plumes that extend from the southwestern corner of the Livermore site. LLNL operates groundwater extraction wells in both on-site and off-site areas. In addition, LLNL maintains an extensive network of groundwater monitoring wells in the off-site area west of Vasco Road.

8.1.1 Physiographic Setting

The general topography of the Livermore site is described in **Chapter 1**. The Livermore Valley groundwater system consists of several semiconfined aquifers. Rainfall from the surrounding hills and seasonal surface water in the arroyos recharges the groundwater system, which flows toward the east-west axis of the valley.

The thickest sediments and aquifers are present in the central and western portions of the Livermore Valley, where they form an important resource for the Zone 7 Water Agency. These sediments comprise two aquifers: the Livermore Formation and overlying alluvium. The Livermore Formation averages about 1000 m in thickness and occupies an area of approximately 250 km^2. The alluvium, which is about 100 m thick, is the principal water-producing aquifer within the valley.

8.1.2 Hydrogeology of the Livermore Site

Sediments at the Livermore site are grouped into four grain-size categories: clay, silt, sand, and gravel. Groundwater flow beneath the site occurs primarily in alluvial sand and gravel deposits, which are bounded by lower permeability clay and silt deposits. The alluvial sediments have been subdivided into nine HSUs beneath the Livermore site. HSUs are defined as sedimentary sequences whose permeable layers show evidence of being hydraulically interconnected. Six of the nine HSUs contain contaminants at concentrations above their MCLs: HSU-1B, -2, -3A, -3B, -4, and -5 (Blake et al. 1995; Hoffman et al. 2003). HSU-1A, -6, and -7 do not contain contaminants of concern above action levels.

8.1.3 Remediation Activities and Monitoring Results

In 2007, LLNL operated 29 groundwater treatment facilities. The 95 groundwater extraction wells and 27 dual extraction wells produced more than 1.1 billion L of groundwater and the treatment facilities removed nearly 71 kg of VOCs. Since remediation began in 1989, approximately 12.9 billion L of groundwater have been treated, resulting in removal of more than 1317 kg of VOCs. Detailed flow and mass removal by treatment facility area is presented in Karachewski et al. (2008).

LLNL also operated 9 soil vapor treatment facilities in 2007. The 31 soil vapor extraction wells and 27 dual extraction wells produced more than 1.5 million m^3 of soil vapor and the treatment facilities removed more than 247 kg of VOCs. During the second quarter of 2007, approximately 104 kg of VOCs were removed from soil vapor. This is the first time that more than 100 kg of VOCs has been removed during a single quarter. Since initial operation, over 8.9 million m^3 of soil vapor has been extracted and treated, removing more than 1300 kg of VOCs from the subsurface. Detailed flow and mass removal by treatment facility area is presented in Karachewski et al. (2008).

In 2007, DOE/LLNL increased its efforts to identify and evaluate innovative technologies that could help accelerate cleanup of source areas at the Livermore site. These efforts, which fall under the heading of Enhanced Source Area Remediation (ESAR) activities, include detailed

hydrogeologic evaluation, numerical modeling, bench-scale laboratory tests, and field pilot tests. A data evaluation and numerical modeling analysis methodology called the Source Area Cleanup Technology Evaluation (SACTE) analysis was developed to evaluate potential technologies to accelerate source area cleanup. The subsurface hydrogeochemical attributes of all 21 source areas at the Livermore site were catalogued and analyzed with respect to groundwater flow and contaminant transport. The SACTE analysis then used those site-specific attributes to determine whether the cleanup technologies being considered for field testing and implementation would be cost effective and have a high likelihood of technical success.

Based on the SACTE analysis, three source areas were selected for conducting ESAR pilot tests in 2007: TFE Eastern Landing Mat, Trailer 5475, and TFD Helipad. The three areas were selected in part because existing infrastructure could be used to reduce the overall cost of the pilot tests. The cleanup technologies selected for evaluation were dynamic wellfield operations for removing residual contamination in the vadose zone, hot air injection and groundwater heating for accelerating contaminant mass removal from both the capillary fringe and the vadose zone, and chemical oxidation and bioremediation for in situ destruction of contaminant mass in the saturated zone. ESAR activities in the three source areas are discussed in Karachewski et al. (2008).

Groundwater concentration and hydraulic data collected and analyzed during 2007 continued to provide evidence for the collapse of off-site contaminant plumes and hydraulic containment along the western and southern boundaries of the site, as well as progress towards cleanup of interior plumes and source areas. This is consistent with the longer-term trends detailed in the 2007 *Third Five-Year Review for the Lawrence Livermore National Laboratory, Livermore Site* (Berg et al. 2007) that show steady cleanup in both off-site and on-site areas.

8.1.4 Environmental Impacts

LLNL strives to reduce risks arising from chemicals released to the environment, to conduct all its restoration activities to protect environmental resources, and to preserve the health and safety of all site workers. LLNL's environmental restoration project is committed to preventing present and future human exposure to contaminated soil and groundwater, preventing further contaminant migration of concentrations above drinking water standards, reducing concentrations of contaminants in groundwater, and minimizing contaminant migration from the unsaturated zone to the underlying groundwater.

Remedial solutions that have been determined to be most appropriate for individual areas of contamination are implemented. The selected remedial solutions, which include groundwater and soil vapor extraction and treatment, have been agreed upon by DOE and the regulatory agencies with public input and are designed to achieve the goals of reducing risks to human health and the environment and satisfying remediation objectives, regulatory standards for chemicals in water and soil, and other state and federal requirements.

8.2 Site 300 CERCLA Project

A number of contaminants were released to the environment during past LLNL Site 300 operations including waste fluid disposal to dry wells, surface spills, piping leaks, burial of debris in unlined pits and landfills, detonations at firing tables, and discharge of rinse water to unlined lagoons. Environmental investigations at Site 300 began in 1981. As a result of these investigations, VOCs, high explosive compounds, tritium, depleted uranium, organosilicate oil, nitrate, perchlorate, polychlorinated biphenyls, dioxins, furans, and metals were identified as contaminants of concern in soil, rock, groundwater, or surface water. This contamination is confined within the site boundaries with the exception of VOCs that are present in three monitor wells near the southern site boundary. LLNL maintains an extensive network of on-site and off-site wells to monitor this contamination. All characterized contaminant release sites that have a CERCLA pathway have been assigned to one of nine OUs based on the nature, extent, and sources of contamination, and topographic and hydrologic considerations. Site 300 was placed on the U.S. Environmental Protection Agency National Priorities List in 1990. Cleanup activities began at Site 300 in 1982 and are ongoing.

Background information for LLNL environmental characterization and restoration activities at Site 300 can be found in Webster-Scholten (1994) and the *Site-Wide Remediation Evaluation Summary Report for Lawrence Livermore National Laboratory Site 300* (Ferry et al. 2006).

8.2.1 Physiographic Setting and Geology of Site 300

Site 300 is located in the southeastern Altamont Hills of the Diablo range. The topography of Site 300 consists of a series of steep hills and canyons generally oriented northwest to southeast. The site is underlain by gently dipping sedimentary bedrock dissected by steep ravines. The bedrock consists of interbedded conglomerates, sandstones, siltstones, and claystones of the late Miocene Neroly Formation (Tn), and a Pliocene nonmarine unit (Tps). The bedrock units are locally overlain by mid- to late-Pleistocene terrace deposits and late-Pleistocene to Holocene floodplain, ravine fill, landslide, and colluvial deposits.

The bedrock within Site 300 has been slightly deformed into several gentle, low-amplitude folds. The locations and characteristics of these folds, in combination with the regional fault and fracture patterns, locally influence groundwater flow within the site.

8.2.2 Contaminant Hydrogeology of Site 300

Site 300 is a large and hydrogeologically diverse site. Due to the steep topography and structural complexity, stratigraphic units and groundwater contained within many of these units are discontinuous across the site. Consequently, site-specific hydrogeologic conditions govern the occurrence and flow of groundwater and the fate and transport of contaminants beneath each OU.

An HSU is a water-bearing zone that exhibits similar hydraulic and geochemical properties. At Site 300, HSUs have been defined consisting of one or more stratigraphic intervals that compose a single hydraulic system within one or more OU. Groundwater movement and contaminant migration in groundwater are discussed in the context of HSUs.

Groundwater contamination at Site 300 occurs in three types of water-bearing zones:

1. Quaternary deposits including the alluvium and weathered bedrock (Qal/WBR HSU), alluvial terrace deposits (Qt), and landslide deposits (Qls HSU).
2. Tertiary perched groundwater in fluvial sands and gravels (Tpsg HSU) and semilithified silts and clay of the Tps HSU.
3. Tertiary Neroly Formation bedrock including the $Tnsc_2$, $Tnbs_2$, $Tnsc_{1b}$ $Tnbs_1$, $Tnbs_0$, and $Tnsc_0$ HSUs.

Groundwater in bedrock is typically present under confined conditions in the southern half of the site but is often unconfined elsewhere. Recharge occurs where saturated alluvial valley fill is in contact with underlying permeable bedrock, and where bedrock strata crop out.

8.2.3 Remediation Activities and Monitoring Results

Cleanup activities were initiated at Site 300 in 1982 and are underway or are in the process of being implemented at all nine OUs. These activities include:

- Operating 20 groundwater and soil vapor extraction and treatment facilities.
- Capping and closing four landfills, six high explosives rinse water lagoons and one high explosives burn pit.
- Removal and/or closure of numerous dry wells throughout the site.
- Removal of contaminated soil from source areas throughout the site.
- Installation and sampling of over 680 groundwater monitor wells to track plume migration and remediation progress.

These remediation efforts have resulted in (1) the elimination of risk to on-site workers from contaminant exposure at eight locations throughout Site 300, (2) a reduction in maximum concentrations of the primary contaminant (VOCs) in Site 300 groundwater by 50% to 99%, and (3) the remediation of VOCs in the eastern General Services Area to meet cleanup standards.

In 2007, LLNL operated 15 groundwater and 5 soil vapor treatment facilities. About 34 million L of groundwater were extracted and treated during 2007. The 18 dual and 2 soil vapor extraction wells removed 1.5 million m^3 of contaminated soil vapor. The Site 300 treatment facilities removed nearly 62 kg of VOCs, 0.1 kg of perchlorate, 390 kg of nitrate, 0.16 kg of the high explosive compound RDX and 0.029 kg of silicone oils (TBOS/TKEBS). Since groundwater remediation began in 1990, approximately 1351 million L of groundwater has been treated, resulting in removal of more than 510 kg of VOCs, 0.7 kg of perchlorate, 5300 kg of nitrate, 0.94 kg of RDX, and 9.4 kg of silicone oils. Detailed flow and mass removal by OU is presented in Dibley et al. (2008).

Construction and buildout of the selected cleanup remedies in the Pit 6 Landfill, High Explosives Process Area, Building 854, and Building 832 Canyon OUs was completed in 2007. Construction was completed for the cleanup remedies at General Services Area, Building 834, and Site-Wide OUs in previous years. Therefore, cleanup remedies have been fully implemented and are operational in seven of the nine OUs at Site 300 to date.

Groundwater concentration and hydraulic data collected and analyzed for Site 300 during 2007 provided evidence of continued progress in reducing contaminant concentrations in Site 300 soil vapor and groundwater, controlling and cleaning up contaminant sources, and mitigating risk to on-site workers. A more detailed description of remediation progress at the Site 300 OUs in 2007 is available in the *2007 Annual Compliance Monitoring Report for LLNL Site 300* (Dibley et al. 2008).

8.2.4 Planned Cleanup Activities

In 2007, a cleanup remedy was selected by the regulatory agencies and DOE for the Pit 7 Complex area in the *Final Amendment to the Interim Site-Wide Record of Decision for the Pit 7 Complex* at *Lawrence Livermore National Laboratory Site 300* (U.S. DOE 2007). In addition, construction began on a drainage diversion system to prevent releases from the Pit 7 Complex landfills and on an extraction and treatment system to remove uranium, VOCs, perchlorate, and nitrate from groundwater in this area. Institutional controls to prevent exposure, and monitoring of contaminants in groundwater are already underway at the Pit 7 Complex.

Cleanup remedies have not yet been selected to address PCB-, dioxin-, and furan-contaminated soil at Building 850; soil and groundwater contamination in Building 812 OU; and for Freon contamination in Building 865 groundwater. In 2007, the *Draft Engineering Evaluation/Cost Analysis for PCB-, Dioxin-, and Furan-contaminated Soil at the Building 850 Firing Table* (Dibley et al. 2007) was submitted to the regulatory agencies. This document presents alternatives for the soil cleanup for regulatory and public consideration and input. The final remedy is scheduled to be selected in an Action Memorandum in 2008. In 2008, a Remedial Investigation/Feasibility Study is scheduled to be submitted for the Building 812 OU. This document will present the results of remedial investigation to characterize contamination and the risk assessment, and present alternatives for the cleanup of soil and groundwater in the Building 812 area for regulatory and public consideration and input. The results of the remedial investigation at Building 865 are still being reviewed by the regulatory agencies.(1)

8.2.5 Environmental Impacts

LLNL strives to reduce elevated risks arising from chemicals released to the environment at Site 300, to conduct its activities to protect ecological resources, and to protect the health and safety of site workers. LLNL's cleanup remedies at Site 300 are designed and implemented to achieve the goals of reducing risks to human health and the environment and satisfying remediation action objectives, meeting cleanup standards for chemicals in water and soil, and preventing contaminant migration in groundwater to the extent technically and economically feasible. These remedies are selected by DOE and the regulatory agencies with public input. These actions include groundwater and soil vapor extraction and treatment; source control through the capping of lagoons and landfills, removal of contaminated soil, and hydraulic drainage diversion; and monitored natural attenuation, monitoring, and institutional controls.

(1) See the Environmental Community Relations website for the status of planned activities. Go to www-envirinfo.llnl.gov and click on "Recently completed environmental documents".

9. Quality Assurance

Donald H. MacQueen, Gene Kumamoto

Quality assurance (QA) is a system of activities and processes put in place to ensure that products or services meet or exceed customer specifications. Quality control (QC) consists of activities used to verify that deliverables are of acceptable quality and meet criteria established in the quality planning process.

9.1 Quality Assurance Activities

Nonconformance reporting and tracking is a formal process used to ensure that problems are identified, resolved, and prevented from recurring. The LLNL EPD tracks problems using nonconformance reports (NCRs). NCRs are initiated when items or activities are identified that do not comply with procedures or other documents that specify requirements for EPD operations or that cast doubt on the quality of EPD reports, integrity of samples, or data *and* that are not covered by other reporting or tracking mechanisms. Many minor sampling or data problems are resolved without an NCR being generated.

LLNL averts sampling problems by requiring formal and informal training on sampling procedures. Errors that occur during sampling generally do not result in lost samples but may require extra work on the part of laboratory or sampling and data management personnel to correct the errors.

LLNL addresses commercial analytical laboratory problems as they arise. Many of the documented problems concern minor documentation errors and are corrected soon after they are identified. Other problems, such as missed holding times, late analytical results, incorrect analysis and typographical errors on data reports, account for the remaining issues. These problems are corrected by the commercial laboratory reissuing reports or correcting paperwork and do not affect associated sample results.

LLNL participates in the Department of Energy Consolidated Auditing Program (DOECAP). Annual, on-site visits to commercial laboratories under contract to LLNL are part of the auditing program to ensure that accurate and defensible data are generated. All commercial laboratories are approved for use as DOE-qualified vendors. LLNL has qualified auditors under the DOECAP program in the areas of quality assurance, organic chemistry, inorganic chemistry, radiochemistry, laboratory information management, and hazardous material management. Audit reports, checklists and Corrective Action Plans are maintained under the DOECAP program for qualified commercial labs. In FY2007, the laboratories certified by the state of California operating at LLNL were not assessed or qualified for EPD use due to budgetary and staff limitations. One commercial laboratory was disqualified under the DOECAP program for data of questionable quality.

9.2 Analytical Laboratories and Laboratory Intercomparison Studies

In 2007, LLNL had Blanket Service Agreements (BSAs) with eight commercial analytical laboratories and used two on-site analytical laboratories. All analytical laboratory services used by LLNL are provided by facilities certified by the State of California. LLNL works closely with these analytical laboratories to minimize problems and ensure that QA objectives are maintained.

LLNL uses the results of intercomparison performance evaluation program data to identify and monitor trends in performance and to draw attention to the need to improve laboratory performance. If a laboratory performs unacceptably for a particular test in two consecutive performance evaluation studies, LLNL may select another laboratory to perform the affected analyses until the original laboratory has demonstrated that the problem has been corrected. If an off-site laboratory continues to perform unacceptably or fails to prepare and implement acceptable corrective action responses, the LLNL Procurement Department formally notifies the laboratory of its unsatisfactory performance. If the problem persists, the off-site laboratory's BSA could be terminated. If an on-site laboratory continues to perform unacceptably, use of that laboratory could be suspended until the problem is corrected.

Although laboratories are also required to participate in laboratory intercomparison programs, permission to publish their results for comparison purposes was not granted for 2007. To obtain Mixed Analyte Performance Evaluation Program (MAPEP) reports that include the results from all participating laboratories, see http://www.inl.gov/resl/mapep/reports.html. MAPEP is a DOE program and the results are publicly available.

9.3 Duplicate Analyses

Duplicate (collocated) samples are distinct samples of the same matrix collected as close to the same point in space and time as possible. Collocated samples that are processed and analyzed by the same laboratory provide intralaboratory information about the precision of the entire measurement system, including sample acquisition, homogeneity, handling, shipping, storage, preparation, and analysis. Collocated samples that are processed and analyzed by different laboratories provide interlaboratory information about the precision of the entire measurement system (U.S. EPA 1987). Collocated samples may also be used to identify errors such as mislabeled samples or data entry errors.

Tables 9-1, **9-2**, and **9-3** present statistical data for collocated sample pairs, grouped by sample matrix and analyte. Samples from both the Livermore site and Site 300 are included. **Tables 9-1** and **9-2** are based on data pairs in which both values are detections (see **Section 9.4**). **Table 9-3** is based on data pairs in which either or both values are nondetections.

When there were more than eight data pairs with both results in each pair considered detections, precision and regression analyses were performed; those results are presented in **Table 9-1**. When there were eight or fewer data pairs with both results above the detection limit, the ratios of the individual duplicate sample pairs were averaged; the mean, minimum, and maximum ratios for

selected analytes are given in **Table 9-2**. The mean ratio should be between 0.7 and 1.3. When either of the results in a pair is a nondetection, the other result should be a nondetection or less than two times the detection limit. **Table 9-3** identifies the sample media and analytes for which at least one pair failed this criterion. Media and analytes with fewer than four pairs are omitted from the table.

Table 9-1. Quality assurance collocated sampling: Summary statistics for analytes with more than eight pairs in which both results were above the detection limit.

Media	Analyte	N	%RSD	Slope	r^2	Intercept
Air	Gross beta	94	19.3	0.989	0.87	1.24×10^{-5} , (Bq/m^3)
	Beryllium[e]	14	8.66	0.907	0.77	0.411 (pg/m^3)
	Uranium-235[d]	12	60.7	2.08	0.3	1.03×10^{-9} (µg/m^3
	Uranium-238[d]	12	73.5	2.73	0.22	2.36×10^{-6} (µg/m^3)
	Uranium-235/ uranium-238[d]	12	22.5	–1.73	0.06	0.018 (ratio)
	Tritium	26	38.9	1.11	0.99	0.000292 (Bq/m^3)
Dose (TLD)	90-day radiological dose[d]	32	3.17	0.895	0.70	1.91 (mrem)
Groundwater	Gross alpha	9	15.4	0.834	0.88	0.0212 (Bq/L)
	Gross beta[d]	53	19.5	0.878	0.42	0.0863 (Bq/L)
	Arsenic	34	7.12	0.984	0.99	–0.000159 (mg/L)
	Barium	29	12.9	0.939	0.92	-8.9×10^{-5} (mg/L)
	Nitrate (as NO_3)	22	4.56	0.974	0.96	1.2 (mg/L)
	Potassium[d]	22	47.1	0.759	0.56	6.64 (mg/L)
	Tritium	11	6.66	1.03	1	–5.96 (Bq/L)
	Uranium-234+ uranium-233	24	13.4	1	0.99	0.00255 (Bq/L)
	Uranium-235	17	21.1	0.867	0.94	0.000467 (Bq/L)
	Uranium-238	22	8.5	0.953	0.99	0.00291 (Bq/L)
	Vanadium[e]	9	2.62	0.241	0.25	0.0442 (mg/L)
Sewer	Gross beta[d]	51	12	0.97	0.64	2.47×10^{-5} (Bq/mL)

(a) Number of collocated pairs included in regression analysis.

(b) 75th percentile of percent relative standard deviations (%RSD) where %RSD = $\left(\frac{200}{\sqrt{2}}\right)\frac{|x_1 - x_2|}{x_1 + x_2}$ where x_1 and x_2 are the reported concentrations of each routine–duplicate pair.

(c) Coefficient of determination.

(d) Outside acceptable range of slope or r^2 because of variability.

(e) Outside acceptable range of slope or r^2 because of outliers.

Table 9-2. Quality assurance collocated sampling: Summary statistics for selected analytes with eight or fewer pairs in which both results were above the detection limit.

Media	Analyte	N[(a)]	Mean ratio	Minimum ratio	Maximum ratio
Air	Gross alpha	3	1.2	0.68	1.6
Groundwater	Plutonium-239+240	1	0.64	0.64	0.64
	Radium-226	5	1	0.62	1.6
	Radium-228	1	1	1	1
OW	Gross alpha	1	1.1	1.1	1.1
	Gross beta	2	0.88	0.79	0.97
Runoff (from rain)	Gross beta	3	0.93	0.73	1.2
	Uranium-233+234	1	0.88	0.88	0.88
	Uranium-238	1	1.3	1.3	1.3
Soil	Gross alpha	1	0.68	0.68	0.68
	Cesium-137	4	1	0.86	1.3
	Tritium	1	0.87	0.87	0.87
	Tritium	1	0.87	0.87	0.87
	Potassium-40	4	1.1	1	1.1
	Plutonium-238	3	0.67	0.56	0.73
	Plutonium-239+240	3	0.91	0.8	1
	Radium-226	4	1.1	0.97	1.2
	Radium-228	4	1.1	1	1.2
	Thorium-228	4	1.1	1	1.1
	Uranium-235	4	1.1	0.98	1.2
	Uranium-238	4	1	0.87	1.2
Vegetation	Tritium	5	0.93	0.48	1.2

(a) Number of collocated pairs used in ratio calculations.

Precision is measured by the percent relative standard deviation (%RSD); see the EPA's *Data Quality Objectives for Remedial Response Activities: Development Process*, Section 4.6 (U.S. EPA 1987). Acceptable values for %RSD vary greatly with matrix, analyte, and analytical method; however, lower values represent better precision. The results for %RSD given in **Table 9-1** are the 75th percentile of the individual precision values. Routine and collocated sample results show good %RSD—90% of the pairs have %RSD of 37% or better; 75% have %RSD of 18% or better.

Table 9-3. Quality assurance collocated sampling: Summary statistics for analytes with at least four pairs in which one or both results were below the detection limit.

Media	Analyte	No. inconsistent pairs[(a)]	No. pairs	Percent inconsistent pairs
Air	Gross alpha	1	97	1
Groundwater	Gross alpha	5	46	11
	Cadmium	1	52	1.9
	Chromium	1	28	3.6
	Copper	1	49	2
	Nickel	1	48	2.1
	Nitrate (as NO_3)	1	8	12
	Vanadium	1	40	2.5
	Zinc	3	51	5.9
Sewer	Gross alpha	4	52	7.7
	Ethanol	2	4	50

(a) Inconsistent pairs are those for which one of the results is more than twice the reporting limit of the other.

Regression analysis consists of fitting a straight line to the collocated sample pairs. Good agreement is indicated when the data lie close to a line with a slope equal to 1 and an intercept equal to 0, as illustrated in **Figure 9-1**. Allowing for normal analytical variation, the slope of the fitted line should be between 0.7 and 1.3, and the absolute value of the intercept should be less than the detection limit. The coefficient of determination (r^2) should be greater than 0.8. These criteria apply to pairs in which both results are above the detection limit.

Collocated sample comparisons are more variable when the members of the pair are analyzed by different methods or with different criteria for analytical precision. For example, radiological analyses using different counting times or different laboratory aliquot sizes will have different amounts of variability. Different criteria are rarely, if ever, used with collocated sample pairs in LLNL environmental monitoring sampling. Different criteria are sometimes used in special studies when more than one regulatory agency is involved.

Data sets that do not meet LLNL regression analysis criteria fall into one of two categories: outliers and high variability. Outliers can occur because of data transcription errors, measurement errors, or real but anomalous results. Of the 19 data sets reported in **Table 9-1**, two did not meet the criterion for acceptability because of outliers. **Figure 9-2** illustrates a set of collocated pairs with two outliers.

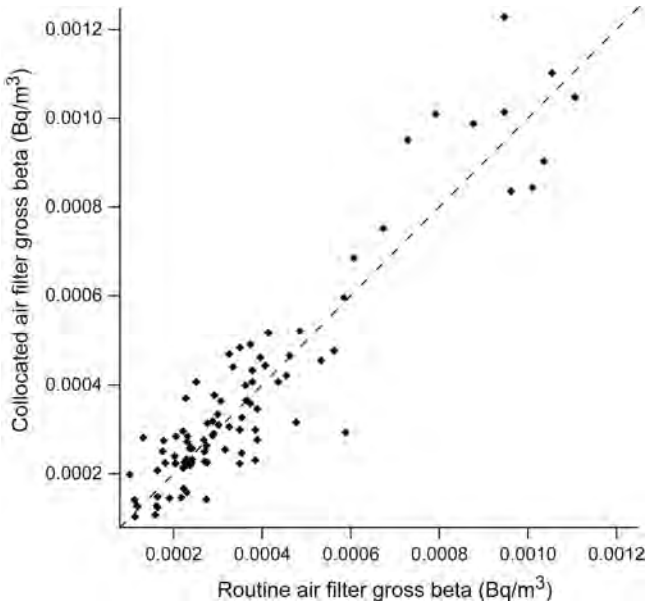

Figure 9-1. Example of data points that demonstrate good agreement between collocated sample results using gross beta concentrations in air

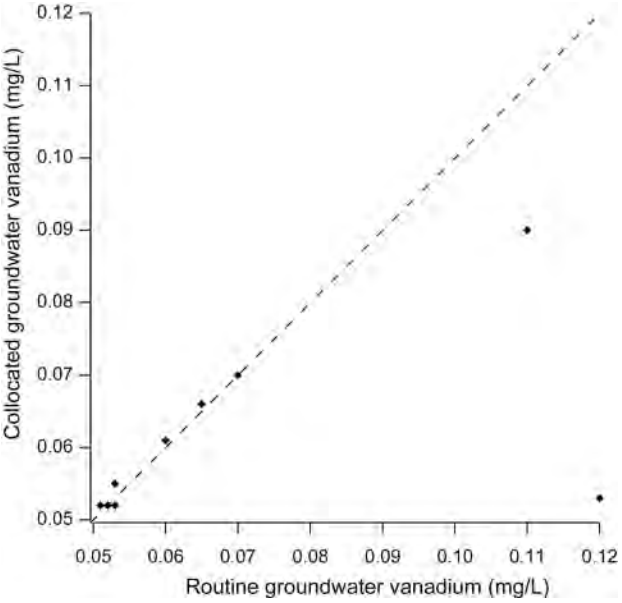

Figure 9-2. Example of data with two outliers using collocated groundwater vanadium concentrations

The second category, high variability, occurs when the measurement process inherently has substantial variability (see **Figure 9-3** for an example). It also tends to occur at extremely low concentrations. Low concentrations of radionuclides on particulates in air highlight this effect because a small number of radionuclide-containing particles on an air filter can significantly affect results. Other causes of high variability are sampling and analytical methodology. Analyses of total organic carbon and total organic halides in water are particularly difficult to control. Of the 19 data sets listed in **Table 9-1**, seven show sufficient variability in the results to make them fall outside the acceptable range.

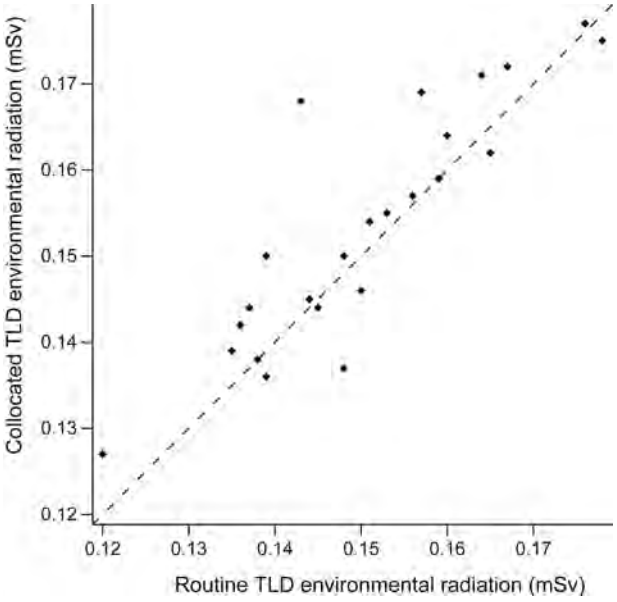

Figure 9-3. Example of variability using 90 day radiological dose measurements from collocated samples

9.4 Data Presentation

The data tables in **Appendix A** were created using computer scripts that retrieve data from a database, convert the data into Système International (SI) units when necessary, calculate summary statistics, format data as appropriate, format the table into rows and columns, and present a draft table. The tables are reviewed by the responsible analyst. Analytical laboratory data and the values calculated from the data are normally displayed with two, or at most three, significant digits. Significant trailing zeros may be omitted.

9.4.1 Radiological Data

Most of the data tables in **Appendix A** display radiological data as a result plus or minus (±) an associated 2σ uncertainty. This measure of uncertainty represents intrinsic variation in the measurement process, most of which is due to the random nature of radioactive decay (see

Section 9.6). The uncertainties are not used in summary statistic calculations. Any radiological result exhibiting a 2σ uncertainty greater than or equal to 100% of the result is considered a nondetection.

Some radiological results are derived from the number of sample counts minus the number of background counts inside the measurement apparatus. Therefore, a sample with a concentration at or near background may have a negative value. Such results are reported in the data tables and used in the calculation of summary statistics and statistical comparisons.

Some data tables provide a limit-of-sensitivity value instead of an uncertainty when the radiological result is below the detection criterion. Such results are displayed with the limit-of-sensitivity value in parentheses.

9.4.2 Nonradiological Data

Nonradiological data reported by the analytical laboratory as being below the reporting limit are displayed in tables with a less-than symbol (<). Reporting limit values are used in the calculation of summary statistics, as explained below.

9.5 Statistical Comparisons and Summary Statistics

Standard comparison techniques such as regression analysis, *t*-tests, and analysis of variance have been used where appropriate to determine the statistical significance of trends or differences between means. When a comparison is made, the results are described as either "statistically significant" or "not statistically significant." Other uses of the word "significant" in this report do not imply that statistical tests have been performed but relate to the concept of practical significance and are based on professional judgment.

Summary statistics are calculated according to Woods (2005). The usual summary statistics are the median, which is a measure of central tendency, and interquartile range (IQR), which is a measure of dispersion (variability). However, some data tables may present other measures at the discretion of the analyst.

The median indicates the middle of the data set (i.e., half of the measured results are above the median, and half are below). The IQR is the range that encompasses the middle 50% of the data set. The IQR is calculated by subtracting the 25th percentile of the data set from the 75th percentile of the data set. When necessary, the percentiles are interpolated from the data. Different software vendors may use slightly different formulas for calculating percentiles. Radiological data sets that include values less than zero may have an IQR greater than the median. In this report, at least four values are required to calculate the median and at least six values are required to calculate the IQR.

Summary statistics are calculated from values that, if necessary, have already been rounded, such as when units have been converted from picocuries to becquerels, and are then rounded to an appropriate number of significant digits. The calculation of summary statistics is also affected by

the presence of nondetections. A nondetection indicates that no specific measured value is available; instead, the best information available is that the actual value is less than the reporting limit. Adjustments to the calculation of the median and IQR for data sets that include nondetections are described below.

For data sets with all measurements above the reporting limit and radiological data sets that include reported values below the reporting limit, all reported values, including any below the reporting limit, are included in the calculation of summary statistics.

For data sets that include one or more values reported as "less than the reporting limit," the reporting limit is used as an upper bound value in the calculation of summary statistics.

If the number of values is odd, the middle value (when sorted from smallest to largest) is the median. If the middle value and all larger values are detections, the middle value is reported as the median. Otherwise, the median is assigned a less-than (<) sign.

If the number of values is even, the median is halfway between the middle two values (i.e., the middle two when the values are sorted from smallest to largest). If both of the middle two values and all larger values are detections, the median is reported. Otherwise, the median is assigned a less-than (<) sign.

If any value used to calculate the 25th percentile is a nondetection, or any value larger than the 25th percentile is a nondetection, the IQR cannot be calculated and is not reported.

The median and the IQR are not calculated for data sets with no detections.

9.6 Reporting Uncertainty in Data Tables

The measurement uncertainties associated with results from analytical laboratories are represented in two ways. The first of these, significant digits, relates to the resolution of the measuring device. For example, if an ordinary household ruler with a metric scale is used to measure the length of an object in centimeters, and the ruler has tick marks every one-tenth of a centimeter, the length can reliably and consistently be measured to the nearest tenth of a centimeter (i.e., to the nearest tick mark). An attempt to be more precise is not likely to yield reliable or reproducible results because it would require a visual estimate of a distance between tick marks. The appropriate way to report a measurement using this ruler would be, for example, 2.1 cm, which would indicate that the "true" length of the object is nearer to 2.1 cm than to 2.0 cm or 2.2 cm (i.e., between 2.05 and 2.15 cm). A measurement of 2.1 cm has two significant digits. Although not stated, the uncertainty is considered to be ± 0.05 cm. A more precise measuring device might be able to measure an object to the nearest one-hundredth of a centimeter; in that case a value such as "2.12 cm" might be reported. This value would have three significant digits and the implied uncertainty would be ± 0.005 cm. A result reported as "3.0 cm" has two significant digits. That is, the trailing zero is significant and implies that the true length is between 2.95 and 3.05 cm—closer to 3.0 than to 2.9 or 3.1 cm.

When performing calculations with measured values that have significant digits, all digits are used. The number of significant digits in the calculated result is the same as that of the measured value with the fewest number of significant digits.

Most unit conversion factors do not have significant digits. For example, the conversion from milligrams to micrograms requires multiplying by the fixed (constant) value of 1000. The value 1000 is exact; it has no uncertainty and therefore the concept of significant digits does not apply.

The other method of representing uncertainty is based on random variation. For radiological measurements, there is variation due to the random nature of radioactive decay. As a sample is measured, the number of radioactive decay events is counted and the reported result is calculated from the number of decay events that were observed. If the sample is recounted, the number of decay events will almost always be different because radioactive decay events occur randomly. Uncertainties of this type are reported as 2σ uncertainties. A 2σ uncertainty represents the range of results expected to occur approximately 95% of the time if a sample were to be recounted many times. A radiological result reported as, for example, "2.6 ± 1.2 Bq/g," would indicate that with approximately 95% confidence, the "true" value is in the range of 1.4 to 3.8 Bq/g (i.e., 2.6 – 1.2 = 1.4 and 2.6 + 1.2 = 3.8). When necessary, results are converted from pCi to Bq by multiplying by 0.037; this introduces extraneous digits that are not significant and should not be shown in data tables. For example, 5.3 pCi/g × 0.037 = 0.1961 Bq/g. The initial value, 5.3, has two significant digits, so the value 0.1961 would be rounded to two significant digits, that is, 0.20.

However, the rounding rule changes when there is a radiological uncertainty associated with a radiological result. In this case, data are presented according to the method recommended in Multi-Agency Radiological Laboratory Analytical Protocols (MARLAP) Section 19.3.7 (U.S. NRC/U.S. EPA 2004). First the uncertainty is rounded to the appropriate number of significant digits, after which the result is rounded to the same number of decimal places. For example, suppose a result and uncertainty after unit conversion are 0.1961 ± 0.05436, and the appropriate number of significant digits is two. First, 0.05436 is rounded to 0.054 (two significant digits). 0.054 has three decimal places, so 0.1961 is then rounded to three decimal places, i.e., 0.196. These would be presented in the data tables as 0.196 ± 0.054.

When rounding a value with a final digit of "5," the software that was used to prepare the data tables follows the IEEE Standard 754−1985, which is "go to the even digit." For example, 2.45 would be rounded down to 2.4, and 2.55 would be rounded up to 2.6.

The software that prepares the data tables pays careful attention to the details of rounding for significant digits. It should be noted, however, that these details are of little practical significance. For example, if a result of 5.6 is incorrectly rounded to 5.5 or 5.7, the introduced "error" is less than 2% (0.1/5.6 = 0.018). Such an error will rarely have any impact on the interpretation of the data with respect to human health or environmental impact.

9.7 Quality Assurance Process for the Environmental Report

Unlike the preceding sections, which focused on standards of accuracy and precision in data acquisition and reporting, this section describes the actions that are taken to ensure the accuracy of this data-rich environmental report, the preparation of which involves many operations and many people. The key elements that are used to ensure accuracy are described below.

Analytical laboratories send reports electronically, which are loaded directly into the database. This practice should result in perfect agreement between the database and data in printed reports from the laboratories. In practice, however, laboratory reporting is not perfect, so the Data Management Team (DMT) carefully checks all incoming data throughout the year to make sure that electronic and printed reports from the laboratories agree. This aspect of QC is essential to the report's accuracy. Because of this ongoing QC of incoming data, data stored in the database and used to prepare the annual environmental report tables are unlikely to contain errors.

As described in **Section 9.4**, scripts are used to pull data from the database directly into the format of the table, including unit conversion and summary statistic calculations. All of the data tables contained in **Appendix A** were prepared for this report in this manner. For these tables, it is the responsibility of the appropriate analyst to check each year that the table is up-to-date (e.g., new locations/analytes added, old ones removed), that the data agree with the data he or she has received from DMT, and that the summary calculations have been done correctly.

For this 2007 environmental report, LLNL staff checked tables and figures in the body of the report. Forms to aid in the QC of tables and figures were distributed along with the appropriate figure, table, and text, and a coordinator kept track of the process. Items that were checked included clarity and accuracy of figure captions and table titles; data accuracy and completeness; figure labels and table headings; units; significant digits; and consistency with text. Completed QC forms and the corrected figures or tables were returned to the report editor, who, in collaboration with the responsible author, ensured that corrections were made.

9.8 Errata

Appendix E contains the protocol for errata in LLNL *Environmental Reports* and the errata for LLNL *Environmental Report 2006*.

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Acronyms and Glossary

Symbols and Units of Measure

ºC	degree centigrade
ºF	degree Fahrenheit
σ	sigma
aCi	attocurie (10^{-18} Ci)
µBq	microbecquerel (10^{-6} Bq)
µg/g	microgram per gram (10^{-6} g/g)
µg/L	microgram per liter (10^{-6} g/L)
µg/m^3	microgram per cubic meter (10^{-6} g/m^3)
µrem	microrem (10^{-6} rem)
µSv/y	microsievert per year
Bq	becquerel (*See also* definition in **Key Terms** section.)
Bq/g	becquerel per gram
Bq/kg	becquerel per kilogram
Bq/L	becquerel per liter
Bq/m^3	becquerel per cubic meter
Bq/mL	becquerel per milliliter
Ci	curie (*See also* definition in **Key Terms** section.)
cm	centimeter
ft	foot
g	gram
gal	gallon
gal/d	gallon per day
gal/min	gallon per minute
GBq	gigabecquerel (10^9 Bq)
in.	inch
keV	kiloelectronvolt (10^3 eV) (*See also* definition of "electronvolt" in **Key Terms** section.)
kg	kilogram (10^3 g)
kg/d	kilogram per day (10^3 g/d)
km	kilometer (10^3 m)
L	liter
L/d	liter per day
L/y	liter per year
m	meter
mBq	millibecquerel (10^{-3} Bq)
mBq/g	millibecquerel per gram (10^{-3} Bq/g)
mBq/dry g	millibecquerel per dry gram (10^{-3} Bq/dry g)
mBq/m^3	millibecquerel per cubic meter (10^{-3} Bq/m^3)
mCi	millicurie (10^{-3} Ci)
mg/L	milligram/liter (10^{-3} g/L)
mi	mile
mph	mile per hour
mrem	millirem (10^{-3} rem) (*See also* definition of "rem" in **Key Terms** section.)
mrem/y	millirem per year (10^{-3} rem/y)
m/s	meter per second
mSv	millisievert (10^{-3} Sv)
mSv/y	millisievert per year (10^{-3} Sv/y)
nBq	nanobecquerel (10^{-9} Bq)

nSv	nanosievert (10^{-9} Sv)
nSv/y	nanosievert per year (10^{-9} Sv/y)
pCi	picocurie (10^{-12} Ci)
pCi/g	picocurie per gram (10^{-12} Ci/g)
pCi/dry g	picocurie per dry gram (10^{-12} Ci/dry g)
pCi/L	picocurie per liter (10^{-12} Ci/liter)
person-Sv	person-sievert (*See also* definition in **Key Terms** section.)
person-Sv/y	person-sievert/year
pg/L	picogram per liter (10^{-12} g/L)
pg/m^3	picogram per cubic meter (10^{-12} g/m^3)
Sv	sievert (*See also* definition in **Key Terms** section.)
TBq	terabecquerel (10^{12} Bq)

Acronyms and Abbreviations

%RSD	Percent relative standard deviation
ACCDA	Alameda County Community Development Agency
ACDEH	Alameda County Department of Environmental Health
ACOE	Army Corps of Engineers
AFV	alternative fuel vehicle
ATSDR	Agency for Toxic Substances and Disease Registry
AHR	(LLNL) Administration and Human Resources (Directorate)
BAAQMD	Bay Area Air Quality Management District (*See also* definition in **Key Terms** section.)
BCG	Biota Concentration Guide
BO	biological opinion
BOD	Biochemical (biological) oxygen demand (*See also* definition in **Key Terms** section.)
BSA	Blanket Service Agreement
BSL	Biosafety Level
CalARP	California Accidental Release Prevention
CAMP	Corrective Action Monitoring Plan
CARB	California Air Resources Board
CCR	California Code of Regulations
CDFG	California Department of Fish and Game
CEI	Compliance Evaluation Inspection
CEQA	California Environmental Quality Act of 1970 (*See also* definition in **Key Terms** section.)
CFF	Contained Firing Facility
CFR	Code of Federal Regulations
CHP	California Highway Patrol
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980 (*See also* definition in **Key Terms** section.)
CMWMA	California Medical Waste Management Act
CNPS	California Native Plant Society
CO	carbon monoxide
COC	constituent of concern
COD	chemical oxygen demand
COMP	(LLNL) Computation (Directorate)
CSA	container storage area
CSU	container storage unit

CUPA	Certified Unified Program Agencies
CVRWQCB	Central Valley Regional Water Quality Control Board (*See also* definition in **Key Terms** section.)
CWA	(Federal) Clean Water Act
CWEA	California Water Environment Association
CX	categorical exclusion
D&D	decontamination and decommissioning
DCG	derived concentration guide (*See also* definition in **Key Terms** section.)
DHS	(California) Department of Health Services
DMP	Detection Monitoring Plan
DMT	Data Management Team
DO	(LLNL) Director's Office
DOE	(U.S.) Department of Energy (*See also* definition in **Key Terms** section.)
DOECAP	(U.S.) Department of Energy Consolidated Auditing Program
DOT	(U.S.) Department of Transportation
DPR	(California) Department of Pesticide Regulation
DTSC	(California Environmental Protection Agency) Department of Toxic Substances Control
DWTF	Decontamination and Waste Treatment Facility
E85	Vehicle fuel, 85% ethanol and 15% gasoline
EA	environmental assessment
EDE	effective dose equivalent (*See also* definition in **Key Terms** section.)
EDO	Environmental Duty Officer
EIS	environmental impact statement
EMP	Environmental Management Plan
EMS	Environmental Management System
EPA	Environmental Protection Agency (*See also* definition in **Key Terms** section.)
EPCRA	Emergency Planning and Community Right-to-Know Act of 1986 (*See also* definition in **Key Terms** section.)
EPD	(LLNL) Environmental Protection Department
EPEAT	Electronic Product Environmental Assessment Tool
EPL	effluent pollutant limit
EPP	Environmentally Preferable Purchasing
ERD	(LLNL) Environmental Restoration Department
ES&H	Environment, Safety, and Health
ESA	Endangered Species Act
ESAR	Enhanced Source Area Remediation
EWSF	Explosives Waste Storage Facility
EWTF	Explosives Waste Treatment Facility
FFA	Federal Facility Agreement (*See also* definition in **Key Terms** section.)
FFCA	Federal Facilities Compliance Act
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FONSI	Finding of No Significant Impact
FY	fiscal year (*See also* definition in **Key Terms** section.)
GAC	granulated activated carbon
GSA	(U.S.) General Services Administration
GWP	(Livermore site) Ground Water Project, or Global Warming Potential
HE	high explosives (*See also* definition in **Key Terms** section.)
HPGe	high-purity germanium
HSU	hydrostratigraphic unit

HT/TT	tritiated hydrogen gas
HTO/TTO	tritiated water or tritiated water vapor
HWCA	Hazardous Waste Control Act (*See also* definition in **Key Terms** section.)
IEEE	Institute of Electrical and Electronics Engineers
IQR	Interquartile range (*See also* definition in **Key Terms** section.)
ISMS	Integrated Safety Management System
ISO	International Organization for Standardization
LEPC	Local Emergency Planning Committee
LLNL	Lawrence Livermore National Laboratory
LLNS	Lawrence Livermore National Security, LLC
LOS	limit of sensitivity
MAPEP	Mixed Analyte Performance Evaluation Program
MAPS	Monitoring Avian Productivity and Survivorship
MARLAP	Multi-Agency Radiological Laboratory Analytical Protocols
MCL	maximum contaminant level (*See also* definition in **Key Terms** section.)
MDC	minimum detectable concentration, or (LLNL) Multi-Directorate Consortium
MRP	Monitoring and Reporting Program
MSDS	material safety data sheet
MT	metric ton
NCR	nonconformance report
NCRP	National Council on Radiation Protection and Measurements
NEPA	National Environmental Policy Act (*See also* definition in **Key Terms** section.)
NESHAPs	National Emissions Standards for Hazardous Air Pollutants
NHI	(LLNL) Nonproliferation, Homeland and International Security (Directorate)
NHPA	National Historic Preservation Act
NIF	National Ignition Facility
NNSA	National Nuclear Security Administration
NOV	notice of violation
NOx	nitrous oxides
NPDES	National Pollutant Discharge Elimination System (*See also* definition in **Key Terms** section.)
NRHP	National Register of Historic Places
OBT	organically bound tritium
ODS	ozone depleting substance
OU	operable unit
P2	pollution prevention
PA	Programmatic Agreement
PAT	(LLNL) Physics and Advanced Technologies (Directorate)
PCB	polychlorinated biphenyl
PCE	perchloroethylene (or perchloroethene); also called tetrachloroethylene or tetrachloroethene
pHMS	(LLNL) pH Monitoring Station
PM-10	particulate matter with diameter equal to or less than 10 micrometer
PPOA	Pollution Prevention Opportunity Assessment
PQL	practical quantitation limit (*See also* definition in **Key Terms** section.)
QA	quality assurance (*See also* definition in **Key Terms** section.)
QC	quality control (*See also* definition in **Key Terms** section.)
RCRA	Resource Conservation and Recovery Act of 1976 (*See also* definition in **Key Terms** section.)
RHWM	(LLNL) Radioactive and Hazardous Waste Management Division
RL	reporting limit
RMA	Radiological Materials Area

ROG/POC	reactive organic gases/precursor organic compounds
ROI	return on investment
RWQCB	Regional Water Quality Control Board (*See also* definition in **Key Terms** section.)
SAA	satellite accumulation area
SACTE	Source Area Cleanup Technology Evaluation
SARA	Superfund Amendment and Reauthorization Act of 1986 (*See also* definition in **Key Terms** section.)
SAT	(LLNL) Space Action Team
SDF	(LLNL) Sewer Diversion Facility
SDWA	Safe Drinking Water Act
SEP	(LLNL) Safety and Environmental Protection (Directorate)
SERC	State Emergency Response Commission
SFBRWQCB	San Francisco Bay Regional Water Quality Control Board (*See also* definition in **Key Terms** section.)
SHPO	State Historic Preservation Officer
SJCEHD	San Joaquin County Environmental Health Department (*See also* definition in **Key Terms** section.)
SJVAPCD	San Joaquin Valley Air Pollution Control District (*See also* definition in **Key Terms** section.)
SMOP	Synthetic Minor Operating Permit
SMS	(LLNL) Sewer Monitoring Station
SOx	sulphur oxides
SPCC	Spill Prevention Control and Countermeasure
STP	Site Treatment Plan
SW-MEI	site-wide maximally exposed individual member (of the public) (*See also* definition in **Key Terms** section.)
SWPPP	Storm Water Pollution Prevention Plan
SWRCB	State Water Resources Control Board
TAG	Technical Assistance Grant
TBOS/TKEBS	tetrabutyly orthosilicate/tetrakis 2-ethylbutyl silane
TCE	trichloroethene (or trichloroethylene)
TEF	toxicity equivalency factor
TEQ	toxicity equivalency
TLD	thermoluminescent dosimeter (*See also* definition in **Key Terms** section.)
TOC	total organic carbon (*See also* definition in **Key Terms** section.)
TOX	total organic halides (*See also* definition in **Key Terms** section.)
TRI	Toxics Release Inventory
Tri-Valley CAREs	Tri-Valley Communities Against a Radioactive Environment
TRU	transuranic (waste) (*See also* definition in **Key Terms** section.)
TSCA	Toxic Substances Control Act
TSDF	treatment, storage, and disposal facility
TSS	total suspended solids (*See also* definition in **Key Terms** section.)
TTO	total toxic organic (compounds)
USFWS	U.S. Fish and Wildlife Service
UVO	ultraviolet ozone
VOC	volatile organic compound (*See also* definition in **Key Terms** section.)
WAA	waste accumulation area (*See also* definition in **Key Terms** section.)
WDAR	Waste Discharge Authorization Requirement
WDR	Waste Discharge Requirement
WGMD	(LLNL) Water Guidance and Monitoring Division
WRD	Water Resources Division (*See also* definition in **Key Terms** section.)

Metric and U.S. Customary Unit Equivalents

	From metric unit to U.S. customary equivalent unit		From U.S. customary unit to metric equivalent unit	
Category	**Metric**	**U.S.**	**U.S.**	**Metric**
Length	1 centimeter (cm)	0.39 inches (in.)	1 inch (in.)	2.54 centimeters (cm)
	1 millimeter (mm)	0.039 inches (in.)		25.4 millimeters (mm)
	1 meter (m)	3.28 feet (ft)	1 foot (ft)	0.3048 meters (m)
		1.09 yards (yd)	1 yard (yd)	0.9144 meters (m)
	1 kilometer (km)	0.62 miles (mi)	1 mile (mi)	1.6093 kilometers (km)
Volume	1 liter (L)	0.26 gallons (gal)	1 gallon (gal)	3.7853 liters (L)
		8.11×10^{-7} acre-feet	1 acre-foot	1.23×10^{6} liters (L)
	1 cubic meter (m^3)	35.32 cubic feet (ft^3)	1 cubic foot (ft^3)	0.028 cubic meters (m^3)
		1.35 cubic yards (yd^3)	1 cubic yard (yd^3)	0.765 cubic meters (m^3)
Weight	1 gram (g)	0.035 ounces (oz)	1 ounce (oz)	28.6 gram (g)
	1 kilogram (kg)	2.21 pounds (lb)	1 pound (lb)	0.373 kilograms (kg)
	1 metric ton (MT)	1.10 short ton (2000 pounds)	1 short ton (2000 pounds)	0.90718 metric ton (MT)
Area	1 hectare (ha)	2.47 acres	1 acre	0.40 hectares (ha)
Radioactivity	1 becquerel (Bq)	2.7×10^{-11} curie (Ci)	1 curie (Ci)	3.7×10^{10} becquerel (Bq)
Radiation dose	1 gray (Gy)	100 rad	1 rad	0.01 gray (Gy)
Radiation dose equivalent	1 sievert (Sv)	100 rem	1 rem	0.01 sievert (Sv)
Temperature	^{o}Fahrenheit = (^{o}Centigrade x 1.8) + 32		^{o}Centigrade = (^{o}Fahrenheit – 32) / 1.8	

Multipying Prefixes

Symbol	Prefix	Factor	Symbol	Prefix	Factor
v	vendeko	10^{-30}	da	deca	10^{1}
x	xenno	10^{-27}	h	hecto	10^{2}
y	yocto	10^{-24}	k	kilo	10^{3}
z	zepto	10^{-21}	M	mega	10^{6}
a	atto	10^{-18}	G	giga	10^{9}
f	femto	10^{-15}	T	tera	10^{12}
p	pico	10^{-12}	P	peta	10^{15}
n	nano	10^{-9}	E	exa	10^{18}
μ	micro	10^{-6}	Z	zetta	10^{21}
m	milli	10^{-3}	Y	yotta	10^{24}
c	centi	10^{-2}			
d	deci	10^{-1}			

Key Terms

Absorbed dose. Amount of energy imparted to matter by ionizing radiation per unit mass of irradiated material, in which the absorbed dose is expressed in units of rad or gray (1 rad = 0.01 gray).

Accuracy. Closeness of the result of a measurement to the true value of the quantity measured.

Action level. Defined by regulatory agencies, the level of pollutants which, if exceeded, requires regulatory action.

Alluvium. Sediment deposited by flowing water.

Alpha particle. Positively charged particle emitted from the nucleus of an atom, having mass and charge equal to those of a helium nucleus (two protons and two neutrons).

Ambient air. Surrounding atmosphere, usually the outside air, as it exists around people, plants, and structures; for monitoring purposes, it does not include air immediately adjacent to emission sources.

Analyte. Specific component measured in a chemical analysis.

Aquifer. Saturated layer of rock or soil below the ground surface that can supply usable quantities of groundwater to wells and springs, and be a source of water for domestic, agricultural, and industrial uses.

Aquitard. Low-permeability geologic formation that bounds an aquifer.

Bay Area Air Quality Management District (BAAQMD). Local agency responsible for regulating stationary air emission sources (including the LLNL Livermore site) in the San Francisco Bay Area.

Becquerel (Bq). SI unit of activity of a radionuclide, equal to the activity of a radionuclide having one spontaneous nuclear transition per second.

Beta particle. Negatively charged particle emitted from the nucleus of an atom, having charge, mass, and other properties of an electron.

Biochemical (biological) oxygen demand (BOD). Measure of the amount of dissolved oxygen that microorganisms need to break down organic matter in water, used as an indicator of water quality.

California Environmental Quality Act of 1970 (CEQA). Statute that requires that all California state, local, and regional agencies document, consider, and disclose to the public the environmental implications of their actions.

Categorical discharge. Discharge from a process regulated by EPA rules for specific industrial categories.

Central Valley Regional Water Quality Control Board (CVRWQCB). Local agency responsible for regulating ground and surface water quality in the Central Valley.

Collective dose equivalent and collective effective dose equivalent. Sums of the dose equivalents or effective dose equivalents to all individuals in an exposed population within 80 km (50 miles) of a radiation source. These are evaluated by multiplying the dose received by an individual at each location by the number of individuals receiving that dose, and summing over all such products for locations within 80 km of the source. They are expressed in units of person-rem or person-sievert. The collective EDE is also referred to as the "population dose."

Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA). Administered by EPA, this federal law**,** also known as Superfund, requires private parties to notify the EPA of conditions that threaten to release hazardous substances or after the release of hazardous substances, and undertake short-term removal and long-term remediation.

Congener. Any particular member of a class of chemical substances, such as dioxins. A specific congener is denoted by a unique chemical structure, for example 2,3,7,8-TCDD.

Cosmic radiation. Radiation with very high energies originating outside the earth's atmosphere; it is one source contributing to natural background radiation.

Curie (Ci). Unit of measurement of radioactivity, defined as the amount of radioactive material in which the decay rate is 3.7×10^{10} disintegrations per second or 2.22×10^{12} disintegrations per minute; one Ci is approximately equal to the decay rate of 1 gram of pure radium.

Depleted uranium. Uranium having a lower proportion of the isotope uranium-238 than is found in naturally occurring uranium. The masses of the three uranium isotopes with atomic weights 238, 235, and 234 occur in depleted

uranium in the weight-percentages 99.8, 0.2, and 5×10^{-4}, respectively. Depleted uranium is sometimes referred to as D-38 or DU.

Derived concentration guide (DCG). Concentrations of radionuclides in water and air that could be continuously consumed or inhaled for one year and not exceed the DOE primary radiation standard to the public (100 mrem/y EDE).

Dose. Energy imparted to matter by ionizing radiation; the unit of absorbed dose is the rad, equal to 0.01 joules per kilogram for irradiated material in any medium.

Dose equivalent. Product of absorbed dose in rad (or gray) in tissue and a quality factor representing the relative damage caused to living tissue by different kinds of radiation, and perhaps other modifying factors representing the distribution of radiation, etc. expressed in units of rem or sievert (1 rem = 0.01 sievert).

Dosimeter. Portable detection device for measuring the total accumulated exposure to ionizing radiation.

Downgradient. In the direction of groundwater flow from a designated area; analogous to downstream.

Effective dose equivalent (EDE). Estimate of the total risk of potential effects from radiation exposure, it is the summation of the products of the dose equivalent and weighting factor for each tissue. The weighting factor is the decimal fraction of the risk arising from irradiation of a selected tissue to the total risk when the whole body is irradiated uniformly to the same dose equivalent. These factors permit dose equivalents from nonuniform exposure of the body to be expressed in terms of an effective dose equivalent that is numerically equal to the dose from a uniform exposure of the whole body that entails the same risk as the internal exposure (ICRP 1980). The effective dose equivalent includes the committed effective dose equivalent from internal deposition of radionuclides and the effective dose equivalent caused by penetrating radiation from sources external to the body, and is expressed in units of rem (or sievert).

Effluent. Liquid or gaseous waste discharged to the environment.

Electronvolt (eV). A unit of energy equal to the amount of kinetic energy gained by an electron when it passes through a potential difference of 1 volt in a vacuum.

Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA). Act that requires facilities that produce, use, or store hazardous substances to report releases of reportable quantities or hazardous substances to the environment.

Environmental impact statement (EIS). Detailed report, required by the National Environmental Policy Act, on the environmental impacts from a federally approved or funded project. An EIS must be prepared by a federal agency when a “major” federal action that will have “significant” environmental impacts is planned.

Federal facility. Facility that is owned or operated by the federal government, subject to the same requirements as other responsible parties when placed on the Superfund National Priorities List.

Federal facility agreement (FFA). Negotiated agreement that specifies required actions at a federal facility as agreed upon by various agencies (e.g., EPA, RWQCB, DOE).

Fiscal year (FY). LLNL’s fiscal year is from October 1 through September 30.

Freon-11. Trichlorofluoromethane.

Freon-113. 1,1,2-trichloro-1,2,2-trifluoroethane; also known as CFC 113.

Gamma ray. High-energy, short-wavelength, electromagnetic radiation emitted from the nucleus of an atom, frequently accompanying the emission of alpha or beta particles.

Groundwater. All subsurface water.

Hazardous waste. Waste that exhibits ignitability, corrosivity, reactivity, and/or EP-toxicity (yielding toxic constituents in a leaching test), and waste that does not exhibit these characteristics but has been determined to be hazardous by EPA. Although the legal definition of hazardous waste is complex, according to EPA the term generally refers to any waste that, if managed improperly, could pose a threat to human health and the environment.

(California) Hazardous Waste Control Act (HWCA). Legislation specifying requirements for hazardous waste management in California.

Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX). High-explosive compound.

High explosives (HE). Materials that release large amounts of chemical energy when detonated.

Inorganic compounds. Compounds that either do not contain carbon or do not contain hydrogen along with carbon, including metals, salts, and various carbon oxides (e.g., carbon monoxide and carbon dioxide).

In situ. Refers to the treatment of contaminated areas in place without excavation or removal, as in the in situ treatment of on-site soils through biodegradation of contaminants.

International Commission on Radiological Protection (ICRP). International organization that studies radiation, including its measurement and effects.

Interquartile range (IQR). Distance between the top of the lower quartile and the bottom of the upper quartile, which provides a measure of the spread of data.

Isotopes. Forms of an element having the same number of protons in their nuclei, but differing numbers of neutrons.

Lake Haussmann. Man-made, lined pond used to capture storm water runoff and treated water at the Livermore site. Formerly called Drainage Retention Basin (DRB).

Less than detection limits. Phrase indicating that a chemical constituent was either not present in a sample, or is present in such a small concentration that it cannot be measured by a laboratory's analytical procedure, and therefore is not identified or not quantified at the lowest level of sensitivity.

Low-level waste. Waste defined by DOE Order 5820.2A, which contains transuranic nuclide concentrations less than 100 nCi/g.

Maximum contaminant level (MCL). Highest level of a contaminant in drinking water that is allowed by the U.S. Environmental Protection Agency or California Department of Health Services.

Metric units. Except for temperature for which specific equations apply, U.S. customary units can be determined from metric units by multiplying the metric units by the U.S. customary equivalent. Similarly, metric units can be determined from U.S. customary equivalent units by multiplying the U.S. customary units by the metric equivalent.(*See also* **Metric and U.S. Customary Unit Equivalents** table in this Glossary.)

Mixed waste. Waste that has the properties of both hazardous and radioactive waste.

National Environmental Policy Act (NEPA). Federal legislation enacted in 1969 that requires all federal agencies to document and consider environmental impacts for federally funded or approved projects and the legislation under which DOE is responsible for NEPA compliance at LLNL.

National Pollutant Discharge Elimination System (NPDES). Federal regulation under the Clean Water Act that requires permits for discharges into surface waterways.

Nuclear Regulatory Commission (NRC). Federal agency charged with oversight of nuclear power and nuclear machinery and applications not regulated by DOE or the Department of Defense.

Nuclide. Species of atom characterized by the constitution of its nucleus. The nuclear constitution is specified by the number of protons, number of neutrons, and energy content; or, alternatively, by the atomic number, mass number, and atomic mass. To be regarded as a distinct nuclide, the atom must be capable of existing for a measurable length of time.

Part B permit. Second, narrative section submitted by generators in the RCRA permitting process that covers in detail the procedures followed at a facility to protect human health and the environment.

Perched aquifer. Aquifer that is separated from another water-bearing stratum by an impermeable layer.

Person-Sievert (person-Sv). The product of the average dose per person times the number of people exposed. 1 person-Sv = 100 person-rem.

pH. Measure of hydrogen ion concentration in an aqueous solution. The pH scale ranges from 0 to 14. Acidic solutions have a pH less than 7; basic solutions have a pH greater than 7; and neutral solutions have a pH of 7.

Pliocene. Geological epoch of the Tertiary period, starting about 12 million years ago.

PM-10. Fine particulate matter with an aerodynamic diameter equal to or less than 10 micrometer.

Point source. Any confined and discrete conveyance (e.g., pipe, ditch, well, stack).

Practical quantitation limit (PQL). Level at which the laboratory can report a value with reasonably low uncertainty (typically 10–20% uncertainty).

Pretreatment. Any process used to reduce a pollutant load before it enters the sewer system.

Quality assurance (QA). System of activities whose purpose is to provide the assurance that standards of quality are attained with a stated level of confidence.

Quality control (QC). Procedures used to verify that prescribed standards of performance are attained.

Quaternary. Geologic era encompassing the last 2 to 3 million years.

Rad. Unit of absorbed dose and the quantity of energy imparted by ionizing radiation to a unit mass of matter such as tissue, and equal to 0.01 joule per kilogram, or 0.01 gray.

Radioactive decay. Spontaneous transformation of one radionuclide into a different nuclide (which may or may not be radioactive), or de-excitation to a lower energy state of the nucleus by emission of nuclear radiation, primarily alpha or beta particles, or gamma rays (photons).

Radioactivity. Spontaneous emission of nuclear radiation, generally alpha or beta particles, or gamma rays, from the nucleus of an unstable isotope.

Radionuclide. Unstable nuclide. See also **nuclide** and **radioactivity**.

Regional Water Quality Control Board (RWQCB). California regional agency responsible for water quality standards and the enforcement of state water quality laws within its jurisdiction. California is divided into nine RWQCBs; the Livermore site is in the San Francisco Bay Region, and Site 300 is in the Central Valley Region.

Rem. Unit of radiation dose equivalent and effective dose equivalent describing the effectiveness of a type of radiation to produce biological effects; coined from the phrase “roentgen equivalent man,” and the product of the absorbed dose (rad), a quality factor (Q), a distribution factor, and other necessary modifying factors. 1 rem = 0.01 sievert.

Resource Conservation and Recovery Act of 1976 (RCRA). Program of federal laws and regulations that govern the management of hazardous wastes, and applicable to all entities that manage hazardous wastes.

Risk assessment. Qualitative and quantitative evaluation of the risk posed to human health and/or the environment by the actual or potential presence and/or use of specific pollutants.

Roentgen (R). Unit of measurement used to express radiation exposure in terms of the amount of ionization produced in a volume of air.

San Francisco Bay Regional Water Quality Control Board (SFBRWQCB). Local agency responsible for regulating ground and surface water quality in the San Francisco Bay Area.

San Joaquin County Environmental Health Department (SJCEHD). Local agency that enforces underground-tank regulations in San Joaquin County, including Site 300.

San Joaquin Valley Air Pollution Control District (SJVAPCD). Local agency responsible for regulating stationary air emission sources (including Site 300) in San Joaquin County.

Sanitary waste. Most simply, waste generated by routine operations that is not regulated as hazardous or radioactive by state or federal agencies.

Saturated zone. Subsurface zone below which all rock pore-space is filled with water; also called the phreatic zone.

Sensitivity. Capability of methodology or instrumentation to discriminate between samples having differing concentrations or containing varying amounts of analyte.

Sievert (Sv). SI unit of radiation dose equivalent and effective dose equivalent, that is the product of the absorbed dose (gray), quality factor (Q), distribution factor, and other necessary modifying factors. 1 sievert = 100 rem.

Site-wide maximally exposed individual (SW-MEI). Hypothetical person who receives, at the location of a given publicly accessible facility (such as a church, school, business, or residence), the greatest LLNL-induced effective dose equivalent (summed over all pathways) from all sources of radionuclide releases to air at a site. Doses at this receptor location caused by each emission source are summed, and yield a larger value than for the location of any other similar public facility. This individual is assumed to continuously reside at this location 24 hours per day, 365 days per year.

Specific conductance. Measure of the ability of a material to conduct electricity; also called conductivity.

Superfund. Common name used for the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA). California has also established a “State Superfund” under provisions of the California Hazardous Waste Control Act.

Superfund Amendments and Reauthorization Act (SARA). Enacted in 1986, these laws amended and reauthorized CERCLA for five years.

Surface impoundment. A facility or part of a facility that is a natural topographic depression, man-made excavation, or diked area formed primarily of earthen materials, although it may be lined with man-made materials. The impoundment is designed to hold an accumulation of liquid wastes, or wastes containing free liquids, and is not an injection well.

Système International d'Unités (SI). International system of physical units which include meter (length), kilogram (mass), kelvin (temperature), becquerel (radioactivity), gray (radioactive dose), and sievert (dose equivalent).

Thermoluminescent dosimeter (TLD). Device used to measure external beta or gamma radiation levels, and which contains a material that, after exposure to beta or gamma radiation, emits light when processed and heated.

Total dissolved solids (TDS). Portion of solid material in a waste stream that is dissolved and passed through a filter.

Total organic carbon (TOC). Sum of the organic material present in a sample.

Total organic halides (TOX). Sum of the organic halides present in a sample.

Total suspended solids (TSS). Total mass of particulate matter per unit volume suspended in water and wastewater discharges that is large enough to be collected by a 0.45 micron filter.

Tritium. Radioactive isotope of hydrogen, containing one proton and two neutrons in its nucleus, which decays at a half-life of 12.3 years by emitting a low-energy beta particle.

Transuranic waste (TRU). Material contaminated with alpha-emitting transuranium nuclides, which have an atomic number greater than 92 (e.g., plutonium-239), half-lives longer than 20 years, and are present in concentrations greater than 100 nCi/g of waste.

Unsaturated zone. Portion of the subsurface in which the pores are only partially filled with water and the direction of water flow is vertical; is also referred to as the vadose zone.

U.S. Department of Energy (DOE). Federal agency responsible for conducting energy research and regulating nuclear materials used for weapons production.

U.S. Environmental Protection Agency (EPA). Federal agency responsible for enforcing federal environmental laws. Although some of this responsibility may be delegated to state and local regulatory agencies, EPA retains oversight authority to ensure protection of human health and the environment.

Vadose zone. Partially saturated or unsaturated region above the water table that does not yield water to wells.

Volatile organic compound (VOC). Liquid or solid organic compounds that have a high vapor pressure at normal pressures and temperatures and thus tend to spontaneously pass into the vapor state.

Waste accumulation area (WAA). Officially designated area that meets current environmental standards and guidelines for temporary (less than 90 days) storage of hazardous waste before pickup by the Radioactive and Hazardous Waste Management Division for off-site disposal.

Wastewater treatment system. Collection of treatment processes and facilities designed and built to reduce the amount of suspended solids, bacteria, oxygen-demanding materials, and chemical constituents in wastewater.

Water Resources Division (WRD). City of Livermore's municipal wastewater treatment plant, which accepts discharges from the LLNL Livermore site. Formerly called Livermore Water Reclamation Plant (LWRP).

Water table. Water-level surface below the ground at which the unsaturated zone ends and the saturated zone begins, and the level to which a well that is screened in the unconfined aquifer would fill with water.

Weighting factor. Tissue-specific value used to calculate dose equivalents which represents the fraction of the total health risk resulting from uniform, whole-body irradiation that could be contributed to that particular tissue.

Zone 7. Common name for the Alameda County Flood Control and Water Conservation District, Zone 7, which is the water agency for the Livermore–Amador Valley with responsibility for regional flood control and drinking water supply.

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APPENDIX A
Data Tables

The data tables listed in this appendix are accessible on CD or https://saer.llnl.gov/. In the electronic version of this appendix, the data tables listed below are linked to the tables, which are read-only Excel files.

A.1 Air Effluent (Chapter 4)

A.1.1 Summary of gross alpha and gross beta (μBq/m$^{3)}$ in background locations for comparison to monitored air effluent emission points in 2007

A.1.2 Summary of gross alpha and gross beta (μBq/m^3) in air effluent samples from monitored emission point at Livermore site, Building 235, 2007

A.1.3 Summary of gross alpha and gross beta (μBq/m^3) in air effluent samples from monitored emission points at Livermore site, Building 251, 2007

A.1.4 Summary of gross alpha and gross beta (μBq/m^3) in air effluent samples from monitored emission points at Livermore site, Building 491, 2007

A.1.5 Summary of gross alpha and gross beta (μBq/m^3) in air effluent samples from monitored emission points at Livermore site, Building 695, 2007

A.1.6 Summary of tritium (Bq/m^3) in air effluent samples from the monitored emission point at Livermore site, Building 695, 2007

A.1.7 Summary of gross alpha and gross beta (μBq/m^3) in air effluent samples from monitored emission points at Livermore site, Building 332, 2007

A.1.8 Summary of tritium in air effluent samples (Bq/m^3) from monitored emission points at Livermore site, Building 331, 2007

A.1.9 Summary of gross alpha and gross beta (μBq/m^3) in air effluent samples from monitored emission points at Site 300, Building 801, 2007

A.2 Ambient Air (Chapter 4)

A.2.1 Tritium concentrations (mBq/m^3) in air near diffuse sources on the Livermore site, 2007

A.2.2 Weekly gross alpha and gross beta concentrations (μBq/m^3) from air particulate samples from the Livermore perimeter locations, 2007

A.2.3 Tritium concentrations (mBq/m^3) in air on the Livermore site, 2007

A.2.4 Beryllium concentration (pg/m^3) in Livermore site and Site 300 air particulate samples, 2007

A.2.5 Beryllium-7 concentrations (mBq/m^3) composite for Livermore site and Site 300 air particulate samples, 2007

A.2.6 Plutonium-239+240 concentrations (nBq/m^3) in air particulate samples from the Livermore perimeter and Site 300 perimeter composite, 2007

A.2.7 Uranium mass concentrations (pg/m^3) in air particulate samples, 2007

A.2.8 Weekly gross alpha and gross beta concentrations (μBq/m^3) from air particulate samples from the Livermore Valley downwind locations, 2007

A.2.9 Tritium concentrations (mBq/m^3) in air, Livermore Valley, 2007

A.2.10 Weekly gross alpha and gross beta concentrations (μBq/m^3) from air particulate samples from Livermore Valley and the special interest location, 2007

A.2.11 Plutonium-239+240 concentrations (nBq/m^3) in air particulate samples from the Livermore Valley and Site 300 perimeter, 2007

A.2.12 Tritium concentrations (mBq/m^3) in air, Site 300, 2007

A.2.13 Weekly gross alpha and gross beta concentrations (μBq/m^3) from air particulate samples from Site 300 and off site, 2007

A. Data Tables

A.3 Livermore Site Wastewater (Chapter 5)

A.4 Storm Water (Chapter 5)

A.5 Livermore Site Groundwater (Chapter 5)

A.6 Site 300 Groundwater (Chapter 5)

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APPENDIX B
EPA Methods of Environmental Water Analysis

Table B-1. Inorganic constituents of concern in water samples, the analytical methods used to determine their concentrations, and their contractual reporting limits.

Constituent of concern		Analytical method	Reporting limit[a,b]
Metals and minerals (mg/L)	All alkalinities	SM 2310	1
	Aluminum	EPA 200.7 or 200.8	0.05 or 0.2
	Ammonia nitrogen (as N)	EPA 350.1 or SM 4500-NH3	0.03 or 0.1
	Antimony	EPA 204.2 or 200.8	0.005
	Arsenic	EPA 206.2 or 200.8	0.002
	Barium	EPA 200.7 or 200.8	0.025 or 0.01
	Beryllium	EPA 210.2 or 200.8	0.0005 or 0.0002
	Boron	EPA 200.7	0.05
	Bromide	EPA 300.0	0.5
	Cadmium	EPA 200.8 or SM 3113B	0.0005
	Calcium	EPA 200.7	0.5
	Chloride	EPA 300.0	1 or 0.5
	Chlorine (residual)	SM-4500-CL	0.1
	Chromium	EPA 218.2 or 200.8	0.01 or 0.001
	Chromium(VI)	EPA 218.4 or 7196	0.002
	Cobalt	EPA 200.7 or 200.8	0.025 or 0.05
	Copper	EPA 220.2, 200.7 or 200.8	0.001, 0.01 or 0.05
	Cyanide	EPA 335.2	0.02
	Fluoride	EPA 340.2 or 340.1	0.05
	Hardness, total (as $CaCO_3$)	SM 2320B	1
	Iron	EPA 200.7 or 200.8	0.1
	Lead	EPA 200.8 or SM3113B	0.002 or 0.005
	Magnesium	EPA 200.7 or 200.8	0.5
	Manganese	EPA 200.7 or 200.8	0.03
	Mercury	EPA 245.2 or 245.1	0.0002
	Molybdenum	EPA 200.7 or 200.8	0.025
	Nickel	EPA 200.7, 200.8 or SM 3113B	0.002, 0.005 or 0.1
	Nitrate (as NO_3)	EPA 353.2 300.0 or SM 4500-NO3	0.5
	Nitrite (as NO_2)	EPA 353.2or 300.0, SM 4500-NO2	0.5
	Ortho-phosphate	EPA 300.0, 365.1 or	0.05
	Perchlorate	EPA 314.0	0.004
	Potassium	EPA 200.7	1
	Selenium	EPA 200.8 or SM 3113B	0.002
	Silver	EPA 200.8 or SM 3113B	0.001 or 0.0005
	Sodium	EPA 200.7	1 or 0.1
	Sulfate	EPA 300.0	1
	Surfactants	SM 5540C	0.5
	Thallium	EPA 279.2 or 200.8	0.001

Table B-1 (cont.). Inorganic constituents of concern in water samples, the analytical methods used to determine their concentrations, and their contractual reporting limits.

Constituent of concern		Analytical method	Reporting limit[a,b]
Metals and minerals (mg/L) (cont.)	Total dissolved solids	SM 2540C	1
	Total suspended solids	SM 2540D	1
	Total Kjeldahl nitrogen (as N)	EPA 351.2 or SM 4500-Norg	0.2
	Total phosphorus (as P)	EPA 365.4 or SM 4500-P	0.05
	Vanadium	EPA 200.7 or 200.8	0.02 or 0.025
	Zinc	EPA 200.7 or 200.8	0.02 or 0.05
General indicator parameters	pH (pH units)	SM 4500-H+	none
	Biochemical oxygen demand (mg/L)	SM 5210B	2
	Conductivity (µS/cm)	EPA 120.1	none
	Chemical oxygen demand (mg/L)	EPA 410.4	5
	Dissolved oxygen (mg/L)	SM 4500-O G	0.05
	Total organic carbon (mg/L)	EPA 9060 or SM 5310B	1
	Total organic halides (mg/L)	EPA 9020	0.02
	Toxicity, acute (fathead minnow)	EPA 600/4-AB5-013	NA
	Toxicity, chronic (fathead minnow)	EPA 1000	NA
	Toxicity, chronic (daphnid)	EPA 1002	NA
	Toxicity, chronic (green algae)	EPA 1003	NA
Radioactivity (Bq/L)	Gross alpha	EPA 900	0.074
	Gross beta	EPA 900	0.11
Radioisotopes (Bq/L)	Americium-241	U-NAS-NS-3050	0.0037
	Plutonium-238	U-NAS-NS-3050	0.0037
	Plutonium-239+240	U-NAS-NS-3050	0.0037
	Radon-222	EPA 913	3.7
	Radium-226	EPA 903	0.0093
	Radium-228	EPA 904	0.037
	Thorium-228	U-NAS-NS-3050	0.009
	Thorium-230	U-NAS-NS-3050	0.006
	Thorium-232	U-NAS-NS-3050	0.006
	Tritium	EPA 906	3.7
	Uranium-234	EPA 907	0.0037
	Uranium-235	EPA 907	0.0037
	Uranium-238	EPA 907	0.0037

(a) The number of decimal places displayed in this table vary by constituent. These variations reflect regulatory agency permit stipulations, or the applicable analytical laboratory contract under which the work was performed, or both.

(b) These reporting limits are for water samples with low concentrations of dissolved solids. If higher concentrations are present, limits are likely to be higher.

Table B-2. Organic constituents of concern in water samples and their contractual reporting limits of concentration, sorted by analytical method.

Constituent of concern	Reporting limit (µg/L)[a,b]
EPA Method 1664	
Oil & Grease	1000
EPA Method 420.1	
Phenolics	5
EPA Method 502.2 (or 524.2)	
1,1,1,2-Tetrachloroethane	0.2
1,1,1-Trichloroethane	0.2
1,1,2,2-Tetrachloroethane	0.2
1,1,2-Trichloroethane	0.2
1,1-Dichloroethane	0.2
1,1-Dichloroethene	0.2
1,1-Dichloropropene	0.2
1,2,3-Trichlorobenzene	0.2
1,2,3-Trichloropropane	0.2
1,2,4-Trichlorobenzene	0.2
1,2,4-Trimethylbenzene	0.2
1,2-Dichlorobenzene	0.2
1,2-Dichloroethane	0.2
1,2-Dichloropropane	0.2
1,3,5-Trimethylbenzene	0.2
1,3-Dichlorobenzene	0.2
1,3-Dichloropropane	0.2
1,4-Dichlorobenzene	0.2
2,2-Dichloropropane	0.2
2-Chlorotoluene	0.2
4-Chlorotoluene	0.2
Benzene	0.2
Bromobenzene	0.2
Bromochloromethane	0.2
Bromodichloromethane	0.2
Bromoform	0.2
Bromomethane	0.2
Carbon tetrachloride	0.2
Chlorobenzene	0.2
Chloroethane	0.2
Chloroform	0.2
Chloromethane	0.2
cis-1,2-Dichloroethene	0.2
cis-1,3-Dichloropropene	0.5
Dibromochloromethane	0.2
Dibromomethane	0.2
Dichlorodifluoromethane	0.2
Ethylbenzene	0.2
Freon 113	0.2
Hexachlorobutadiene	0.2
Isopropylbenzene	0.2
m- and *p*-Xylene isomers	0.2
Methylene chloride	0.2
n-Butylbenzene	0.2
n-Propylbenzene	0.2
Naphthalene	0.2
o-Xylene	0.2
Isopropyl toluene	0.2
sec-Butylbenzene	0.2
Styrene	0.2
tert-Butylbenzene	0.2
Tetrachloroethene	0.2
Toluene	0.2
trans-1,2-Dichloroethene	0.2
trans-1,3-Dichloropropene	0.2
Trichloroethene	0.2
Trichlorofluoromethane	0.2
Vinyl chloride	0.2
EPA Method 507	
Alachlor	0.5
Atraton	0.5
Atrazine	0.5
Bromacil	0.5
Butachlor	0.5
Diazinon	0.5
Dichlorvos	0.5
Ethoprop	0.5
Merphos	0.5
Metolachlor	0.5
Metribuzin	0.5
Mevinphos	0.5
Molinate	0.5
Prometon	0.5

Table B-2 (cont.). Organic constituents of concern in water samples and their contractual reporting limits of concentration, sorted by analytical method.

Constituent of concern	Reporting limit (µg/L)[a,b]
EPA Method 507 (cont.)	
Prometryn	0.5
Simazine	0.5
Terbutryn	0.5
EPA Method 524.2	
1,1,1,2-Tetrachloroethane	1
1,1,1-Trichloroethane	1
1,1,2,2-Tetrachloroethane	1
1,1,2-Trichloroethane	1
1,1-Dichloroethane	1
1,1-Dichloroethene	1
1,1-Dichloropropene	1
1,2,3-Trichlorobenzene	1
1,2,3-Trichloropropane	1
1,2,4-Trichlorobenzene	1
1,2,4-Trimethylbenzene	1
1,2-Dibromo-3-chloropropane	2
1,2-Dichlorobenzene	1
1,2-Dichloroethane	1
1,2-Dichloropropane	1
1,3,5-Trimethylbenzene	1
1,3-Dichlorobenzene	1
1,3-Dichloropropane	1
1,4-Dichlorobenzene	1
2-Chlorotoluene	1
4-Chlorotoluene	1
Benzene	1
Bromobenzene	1
Bromodichloromethane	1
Bromoform	1
Bromomethane	2
Carbon tetrachloride	1
Chlorobenzene	1
Chloroethane	2
Chloroform	1
Chloromethane	2
cis-1,2-Dichloroethene	1
cis-1,3-Dichloropropene	1
Dibromochloromethane	1
Dibromomethane	1
Dichlorodifluoromethane	2
Ethylbenzene	1
Ethylene dibromide	1
Freon-113	1
Hexachlorobutadiene	1
Isopropylbenzene	1
m- and *p*-Xylene isomers	1
Methylene chloride	1
n-Butylbenzene	1
n-Propylbenzene	1
Naphthalene	1
o-Xylene	1
Isopropyl toluene	1
sec-Butylbenzene	1
Styrene	1
tert-Butylbenzene	1
Tetrachloroethene	1
Toluene	1
trans-1,2-Dichloroethene	1
trans-1,3-Dichloropropene	1
Trichloroethene	0.5
Trichlorofluoromethane	1
Vinyl chloride	2
EPA Method 525	
2,4-Dinitrotoluene	0.5
2,6-Dinitrotoluene	0.5
4,4'-DDD	0.5
4,4'-DDE	0.5
4,4'-DDT	0.5
Acenaphthylene	0.5
Alachlor	0.5
Aldrin	0.5
Anthracene	0.5
Aroclor 1016 (PCB)	0.5
Aroclor 1221 (PCB)	0.5
Aroclor 1232 (PCB)	0.5
Aroclor 1242 (PCB)	0.5
Aroclor 1248 (PCB)	0.5

Table B-2 (cont.). Organic constituents of concern in water samples and their contractual reporting limits of concentration, sorted by analytical method.

Constituent of concern	Reporting limit (µg/L)[a,b]
EPA Method 525 (cont.)	
Aroclor 1254 (PCB)	0.5
Aroclor 1260 (PCB)	0.5
Atraton	0.5
Atrazine	0.5
Benzo(a)anthracene	0.5
Benzo(a)pyrene	0.5
Benzo(b)fluoranthene	0.5
Benzo(g,h,i)perylene	0.5
Benzo(k)fluoranthene	0.5
Bis(2-ethylhexyl)phthalate	0.5
Bromacil	0.5
Butachlor	0.5
Butylbenzylphthalate	0.5
Chlordane	0.5
Chloropropham	0.5
Chlorpyrifos	0.5
Chrysene	0.5
Di (2-ethylhexyl) adipate	0.5
Di-n-butylphthalate	0.5
Diazinon	0.5
Dibenzo(a,h)anthracene	0.5
Dichlorvos	0.5
Dieldrin	0.5
Diethylphthalate	0.5
Dimethylphthalate	0.5
Disulfoton	0.5
Endosulfan I	0.5
Endosulfan II	0.5
Endosulfan sulfate	0.5
Endrin	0.5
Endrin aldehyde	0.5
Ethoprop	0.5
Fluorene	0.5
Heptachlor	0.5
Heptachlor epoxide	0.5
Hexachlorobenzene	0.5
Hexachlorocyclopentadiene	0.5
Indeno(1,2,3-c,d)pyrene	0.5
Isophorone	0.5
Lindane	0.5
Merphos	0.5
Methoxychlor	0.5
Metolachlor	0.5
Metribuzin	0.5
Mevinphos	0.5
Pentachlorobenzene	0.5
Pentachlorophenol	0.5
Phenanthrene	0.5
Prometon	0.5
Prometryne	0.5
Propachlor	0.5
Pyrene	0.5
Simazine	0.5
Stirophos	0.5
Terbutryn	0.5
Toxaphene	0.5
EPA Method 547	
Glyphosate 20	20
EPA Method 601	
1,1,1-Trichloroethane	0.5
1,1,2,2-Tetrachloroethane	0.5
1,1,2-Trichloroethane	0.5
1,1-Dichloroethane	0.5
1,1-Dichloroethene	0.5
1,2-Dichlorobenzene	0.5
1,2-Dichloroethane	0.5
1,2-Dichloroethene (total)	0.5
1,2-Dichloropropane	0.5
1,3-Dichlorobenzene	0.5
1,4-Dichlorobenzene	0.5
2-Chloroethylvinylether	0.5
Bromodichloromethane	0.5
Bromoform	0.5
Bromomethane	0.5
Carbon tetrachloride	0.5
Chlorobenzene	0.5
Chloroethane	0.5

Table B-2 (cont.). Organic constituents of concern in water samples and their contractual reporting limits of concentration, sorted by analytical method.

Constituent of concern	Reporting limit (µg/L)[a,b]
EPA Method 601 (cont.)	
Chloroform	0.5
Chloromethane	0.5
cis-1,2-Dichloroethene	0.5
cis-1,3-Dichloropropene	0.5
Dibromochloromethane	0.5
Dichlorodifluoromethane	0.5
Freon-113	0.5
Methylene chloride	0.5
Tetrachloroethene *trans*-1,2-	0.5
Dichloroethene *trans*-1,3-	0.5
Dichloropropene	0.5
Trichloroethene	0.5
Trichlorofluoromethane	0.5
Vinyl chloride	0.5
EPA Method 602	
1,2-Dichlorobenzene	0.3
1,3-Dichlorobenzene	0.3
1,4-Dichlorobenzene	0.3
Benzene	0.4
Chlorobenzene	0.3
Ethylbenzene	0.3
m-Xylene isomers	0.4
o-Xylene	0.4
p-Xylene	0.4
Toluene	0.3
Total xylene isomers	0.4
EPA Method 608	
Aldrin	0.05
BHC, alpha isomer	0.05
BHC, beta isomer	0.05
BHC, delta isomer	0.05
BHC, gamma isomer (Lindane)	0.05
Chlordane	0.2
Dieldrin	0.1
Endosulfan I	0.05
Endosulfan II	0.1
Endosulfan sulfate	0.1
Endrin	0.1
Endrin aldehyde	0.1
Heptachlor	0.05
Heptachlor epoxide	0.05
Methoxychlor	0.5
4,4'-DDD	0.1
4,4'-DDE	0.1
4,4'-DDT	0.1
Toxaphene	1
EPA Method 615	
2,4,5-T	0.5
2,4,5-TP (Silvex)	0.2
2,4-D	1
2,4-Dichlorophenoxy acetic acid	2
Dalapon	10
Dicamba	1
Dichloroprop	2
Dinoseb	1
MCPA	250
MCPP	250
EPA Method 624	
1,1,1-Trichloroethane	1
1,1,2,2-Tetrachloroethane	1
1,1,2-Trichloroethane	1
1,1-Dichloroethane	1
1,1-Dichloroethene	1
1,2-Dichlorobenzene	1
1,2-Dichloroethane	1
1,2-Dichloroethene (total)	1
1,2-Dichloropropane	1
1,3-Dichlorobenzene	1
1,4-Dichlorobenzene	1
2-Butanone	20
2-Chloroethylvinylether	20
2-Hexanone	20
4-Methyl-2-pentanone	20
Acetone	10
Benzene	1

Table B-2 (cont.). Organic constituents of concern in water samples and their contractual reporting limits of concentration, sorted by analytical method.

Constituent of concern	Reporting limit (µg/L)[a,b]
EPA Method 624 (cont.)	
Bromodichloromethane	1
Bromoform	1
Bromomethane	2
Carbon disulfide	1
Carbon tetrachloride	1
Chlorobenzene	1
Chloroethane	2
Chloroform	1
Chloromethane	2
cis-1,2-Dichloroethene	1
cis-1,3-Dichloropropene	1
Dibromochloromethane	1
Dibromomethane	1
Dichlorodifluoromethane	2
Ethylbenzene	1
Freon 113	1
Methylene chloride	1
Styrene	1
Tetrachloroethene	1
Toluene	1
Total xylene isomers	2
trans-1,2-Dichloroethene	1
trans-1,3-Dichloropropene	1
Trichloroethene	0.5
Trichlorofluoromethane	1
Vinyl acetate	1
Vinyl chloride	1
EPA Method 625	
1,2,4-Trichlorobenzene	5
1,2-Dichlorobenzene	5
1,3-Dichlorobenzene	5
1,4-Dichlorobenzene	5
2,4,5-Trichlorophenol	5
2,4,6-Trichlorophenol	5
2,4-Dichlorophenol	5
2,4-Dimethylphenol	5
2,4-Dinitrophenol	25
2,4-Dinitrotoluene	5
2,6-Dinitrotoluene	5
2-Chloronaphthalene	5
2-Chlorophenol	5
2-Methylphenol	5
2-Methyl-4,6-dinitrophenol	25
2-Methylnaphthalene	5
2-Nitroaniline	25
3,3'-Dichlorobenzidine	10
3-Nitroaniline	25
4-Bromophenylphenylether	5
4-Chloro-3-methylphenol	10
4-Chloroaniline	10
4-Chlorophenylphenylether	5
4-Nitroaniline	25
4-Nitrophenol	25
Acenaphthene	25
Acenaphthylene	5
Anthracene	5
Benzo[*a*]a nthracene	5
Benzo[*a*]p yrene	5
Benzo[*b*]f luoranthene	5
Benzo[*g,h,i*]p erylene	5
Benzo[*k*]fluoranthene	5
Benzoic acid	25
Benzyl alcohol	10
Bis(2-chloroethoxy)methane	5
Bis(2-chloroisopropyl)ether	5
Bis(2-ethylhexyl)phthalate	5
Butylbenzylphthalate	5
Chrysene	5
Di-*n*-butylphthalate	5
Di-*n*-octylphthalate	5
Dibenzo[*a,h*]a nthracene	5
Dibenzofuran	5
Diethylphthalate	5
Dimethylphthalate	5
Fluoranthene	5
Fluorene	5
Hexachlorobenzene	5

Table B-2 (cont.). Organic constituents of concern in water samples and their contractual reporting limits of concentration, sorted by analytical method.

Constituent of concern	Reporting limit (µg/L)[a,b]
EPA Method 625 (cont.)	
Hexachlorobutadiene	5
Hexachlorocyclopentadiene	5
Hexachloroethane	5
Indeno[*1,2,3-c,d*]p yrene	5
Isophorone	5
m- and *p*-Cresol	5
N-Nitroso-di-*n*-propylamine	5
Naphthalene	5
Nitrobenzene	5
Pentachlorophenol	5
Phenanthrene	5
Phenol	5
Pyrene	5
EPA Method 632	
Diuron	0.1
EPA Method 8082	
Polychlorinated biphenyls (PCBs)	0.5
EPA Method 8140	
Bolstar	1
Chlorpyrifos	1
Coumaphos	1
Demeton	1
Diazinon	1
Dichlorvos	1
Disulfoton	1
Ethoprop	1
Fensulfothion	1
Fenthion	1
Merphos	1
Methyl Parathion	1
Mevinphos	1
Naled	1
Phorate	1
Prothiophos	1
Ronnel	1
Stirophos	1
Trichloronate	1
EPA Method 8260	
1,1,1,2-Tetrachloroethane	0.5
1,1,1-Trichloroethane	0.5
1,1,2,2-Tetrachloroethane	0.5
1,1,2-Trichloroethane	0.5
1,1-Dichloroethane	0.5
1,1-Dichloroethene	0.5
1,2,3-Trichloropropane	0.5
1,2-Dibromo-3-chloropropane	0.5
1,2-Dichloroethane	0.5
1,2-Dichloroethene (total)	0.5
1,2-Dichloropropane	0.5
2-Butanone	0.5
2-Chloroethylvinylether	0.5
2-Hexanone	0.5
4-Methyl-2-pentanone	0.5
Acetone	10
Acetonitrile	100
Acrolein	50
Acrylonitrile	50
Benzene	0.5
Bromodichloromethane	0.5
Bromoform	0.5
Bromomethane	0.5
Carbon disulfide	5
Carbon tetrachloride	0.5
Chlorobenzene	0.5
Chloroethane	0.5
Chloroform	0.5
Chloromethane	0.5
Chloroprene	5
Dibromochloromethane	0.5
Dichlorodifluoromethane	0.5
Ethanol	1000
Ethylbenzene	0.5
Freon-113	0.5
Methylene chloride	0.5
Styrene	0.5
Tetrachloroethene	0.5
Toluene	0.5
Total xylene isomers	0.5
Trichloroethene	0.5
Trichlorofluoromethane	0.5
Vinyl acetate	20
Vinyl chloride	0.5
cis-1,2-Dichloroethene	0.5
cis-1,3-Dichloropropene	0.5
trans-1,2-Dichloroethene	0.5
trans-1,3-Dichloropropene	0.5

Table B-2 (cont.). Organic constituents of concern in water samples and their contractual reporting limits of concentration, sorted by analytical method.

Constituent of concern	Reporting limit (µg/L)[a,b]
EPA Method 8290	
1,2,3,4,6,7,8-HpCDD	0.00025
1,2,3,4,6,7,8-HpCDF	0.00025
1,2,3,4,7,8,9-HpCDF	0.00025
1,2,3,4,7,8-HxCDF	0.00025
1,2,3,6,7,8-HxCDD	0.00025
1,2,3,6,7,8-HxCDF	0.00025
1,2,3,7,8,9-HxCDD	0.00025
1,2,3,7,8,9-HxCDF	0.00025
1,2,3,7,8-PeCDD	0.0001
1,2,3,7,8-PeCDF	0.0001
2,3,4,6,7,8-HxCDF	0.00025
2,3,4,7,8-PeCDF	0.0001
2,3,7,8-TCDD	0.0001
2,3,7,8-TCDF	0.0001
OCDD	0.0005
OCDF	0.0005
EPA Method 8330	5 or 1
HMX[c]	5 or 1
RDX[d]	5
TNT[e]	0.0001
EPA Method 9131 or Standard Method 9221	MPN[f]/100mL
Fecal coliform bacteria	1 to 2
Total coliform bacteria	1 to 2

(a) The number of decimal places displayed in this table vary by constituent. These variations reflect regulatory agency permit stipulations, the applicable analytical laboratory contract under which the work was performed, or both.

(b) These reporting limits are for water samples with low concentrations of dissolved solids. If higher concentrations are present, limits are likely to be higher.

(c) HMX is octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.

(d) RDX is hexahydro-1,3,5-trinitro-1,3,5-triazine.

(e) TNT is 2,4,6-trinitrotoluene.

(f) MPN = most probable number (of organisms).

Table B-3. Radioisotopes and reporting limits for gamma spectroscopic analysis of constituents of concern in groundwater.[a]

Constituent of concern[b]	Typical reporting limit (Bq/L)
Actinium-228	3.1
Americium-241	1.8
Beryllium-7	3.7
Cesium-134	0.4
Cesium-137	0.3
Cobalt-57	0.2
Cobalt-60	0.4
Europium-152	0.9
Europium-154	1.0
Europium-155	1.0
Potassium-40	7.2
Radium-226	0.8
Thorium-228	0.5
Thorium-234	1.4
Uranium-235	1.3

(a) The significant figures displayed in this table vary by constituents of concern. These variations reflect the applicable analytical laboratory contract under which the work was performed.

(b) Not included are promethium-147 and thallium-208, reported above 46,000 and 72 Bq/L, respectively.

APPENDIX C
Wildlife Survey Results

Table C-1. Site 300 wildlife species list. Includes species for which there are verified observations; it is not intended to be a complete list of Site 300 species.

Taxa	Common Name	Scientific Name	Regulatory Status[(a)]	Source
Mammals	Pallid bat	*Antrozous pallidus*	CASCS	Rainey 2003
	Western red bat	*Lasiurus blossevillii*		Rainey 2003
	Hoary bat	*Lasiurus cinereus*		Rainey 2003
	California myotis	*Myotis californicus*		Rainey 2003
	Western pipistrelle	*Pipistrellus hesperus*		Rainey 2003
	Brazilian free-tailed bat	*Tadarida brasiliensis*		Rainey 2003
	Desert cottontail	*Sylvilagus audubonii*		LLNL 2002; Clark et al. 2002
	Black-tailed jackrabbit	*Lepus californicus*		LLNL 2002; Clark et al. 2002
	Heermann's kangaroo rat	*Dipodomys heermanni*		LLNL 2002; West 2002
	California pocket mouse	*Chaetodipus californicus*	CASCS	LLNL 2002; West 2002
	San Joaquin pocket mouse	*Perognathus inornatus*		Clark et al. 2002
	California ground squirrel	*Spermophilus beecheyi*		LLNL 2002
	Valley pocket gopher	*Thomomys bottae*		LLNL 2002; West 2002
	California vole	*Microtus californicus*		LLNL 2002; West 2002
	House mouse	*Mus musculus*		LLNL 2002; West 2002
	Dusky-footed woodrat	*Neotoma fuscipes*		LLNL 2002; West 2002
	Brush mouse	*Peromyscus boylii*		LLNL 2002; West 2002
	Deer mouse	*Peromyscus maniculatus*		LLNL 2002; West 2002
	Western harvest mouse	*Reithrodontomys megalotis*		LLNL 2002; West 2002
	Coyote	*Canis latrans*		LLNL 2002; Clark et al. 2002
	Raccoon	*Procyon lotor*		LLNL 2002; Orloff 1986
	Long-tailed weasel	*Mustela frenata*		LLNL 2002 ; Orloff 1986
	Striped skunk	*Mephitis mephitis*		LLNL 2002; Orloff 1986
	Western spotted skunk	Spilogale gracilis		LLNL 2002; Orloff 1986
	American badger	Taxidea taxus	CASCS	LLNL 2002; Clark et al. 2002
	Bobcat	Lynx rufus		LLNL 2002; Clark et al. 2002
	Mountain Lion	Felis concolor		LLNL 2002
	Mule deer	Odocoileus hemionus		LLNL 2002; Clark et al. 2002
	Wild pig	Sus scrofa		LLNL 2002; Clark et al. 2002
Herpetofauna	Arboreal salamander	*Aneides lugubris*		Woollett 2005
	California tiger salamander	*Ambystoma californiense*	FT, CASCS	LLNL 2002
	California slender salamander	*Batrachoseps attenuatus*		Burkholder 2008
	California red-legged frog	*Rana aurora draytonii*	FT, CASCS	LLNL 2002
	Pacific treefrog	*Pseudacris regilla*		LLNL 2002

Table C-1 (cont.). Site 300 wildlife species list. Includes species for which there are verified observations; it is not intended to be a complete list of Site 300 species.

Taxa	Common Name	Scientific Name	Regulatory Status[(a)]	Source
Herpetofauna (cont.)	Western spadefoot toad	*Spea hammondii*	CASCS	LLNL 2002
	Western toad	*Bufo boreas*		LLNL 2002
	Alameda whipsnake	*Masticophis lateralis euryxanthus*	FT, ST	Swaim 2002
	San Joaquin coachwhip	*Masticophis flagellum*	CASCS	LLNL 2002
	Coast horned lizard	*Phrynosoma coronatum*	CASCS	LLNL 2002
	California legless lizard	*Anniella pulchra*	CASCS	Swaim 2002
	Side-blotched lizard	*Uta stansburiana*		LLNL 2002; Swaim 2002
	Western whiptail	*Cnemidophorus tigris*		LLNL 2002; Swaim 2002
	Western fence lizard	*Sceloporus occidentalis*		LLNL 2002; Swaim 2002
	Western skink	*Eumeces skiltonianus*		LLNL 2002; Swaim 2002
	Gilbert skink	*Eumeces gilberti*		LLNL 2002; Swaim 2002
	Southern alligator lizard	*Gerrhonotus multicarinatus*		LLNL 2002; Swaim 2002
	Western yellow bellied racer	*Coluber constrictor*		LLNL 2002; Swaim 2002
	Pacific gopher snake	*Pituophis melanoleucus*		LLNL 2002; Swaim 2002
	Common kingsnake	*Lampropeltis getulus*		LLNL 2002; Swaim 2002
	Western rattlesnake	*Crotalus viridis*		LLNL 2002; Swaim 2002
	Night snake	*Hypsiglena torquata*		LLNL 2002; Swaim 2002
	Glossy snake	*Arizona elegans*		LLNL 2002; Swaim 2002
	Long-nosed snake	*Rhinocheilus lecontei*		LLNL 2002; Swaim 2002
	California black-headed snake	*Tantilla planiceps*		Swaim 2002
Birds	Cooper's Hawk	*Accipiter cooperii*	CASCS, MBTA	LLNL 2003
	Sharp-shinned Hawk	*Accipiter striatus*	CASCS, MBTA	LLNL 2003
	Golden Eagle	*Aquila chrysaetos*	CAFPS, CASCS, MBTA	LLNL 2003
	Red-tailed Hawk	*Buteo jamaicensis*	MBTA	LLNL 2003
	Rough-legged Hawk	*Buteo lagopus*	MBTA	LLNL 2003
	Red-shouldered Hawk	*Buteo lineatus*	MBTA	LLNL 2003
	Ferruginous Hawk	*Buteo regalis*	CASCS, MBTA	LLNL 2003
	Swainson's Hawk	*Buteo swainsoni*	ST, MBTA	LLNL 2003
	Northern Harrier	*Circus cyaneus*	CASCS, MBTA	LLNL 2003
	White-tailed Kite	*Elanus leucurus*	CAFPS, MBTA	LLNL 2003
	Osprey	*Pandion haliaetus*	CASCS, MBTA	LLNL 2003
	Bushtit	*Psaltriparus minimus*	MBTA	LLNL 2003
	Horned Lark	*Eremophila alpestris*	CASCS, MBTA	LLNL 2003
	Northern Shoveler	*Anas clypeata*	MBTA	LLNL 2003
	Cinnamon Teal	*Anas cuamptera*	MBTA	LLNL 2003

Table C-1 (cont.). Site 300 wildlife species list. Includes species for which there are verified observations; it is not intended to be a complete list of Site 300 species.

Taxa	Common Name	Scientific Name	Regulatory Status[a]	Source
Birds (cont.)	Mallard	*Anas platyryynchos*	MBTA	LLNL 2003
	Bufflehead	*Blucephala albeola*	MBTA	LLNL 2003
	Common Goldeneye	*Bucephala clangula*	MBTA	LLNL 2003
	White-throated Swift	*Aeronautes saxatalis*	MBTA	LLNL 2003
	Great Egret	*Ardea alba*	MBTA	LLNL 2003
	Virginia Rail	*Rallus limicola*	MBTA	U.S. DOE and UC 1992
	Cedar Waxwing	*Bombycilla garrulus*	MBTA	LLNL 2003
	Common Poorwill	*Phalaenoptilus nuttalii*	MBTA	LLNL 2003
	Blue-grosbeak	*Guiraca caerulea*	MBTA	LLNL 2003
	Black-headed Grosbeak	*Pheucticus melanocephalus*	MBTA	U.S. DOE and UC 1992
	Lazuli Bunting	*Passerina amoena*	MBTA	LLNL 2003
	Turkey Vulture	*Cathartes aura*	MBTA	LLNL 2003
	Killdeer	*Charadrius vociferus*	MBTA	LLNL 2003
	Rock Dove	*Columba livia*		U.S. DOE and UC 1992
	Mourning Dove	*Zenaida macroura*	MBTA	LLNL 2003
	Western Scrub Jay	*Aphelocoma californica*	MBTA	LLNL 2003
	American Crow	*Corvus brachyrhynchos*	MBTA	LLNL 2003
	Common Raven	*Corvus corax*	MBTA	LLNL 2003
	Greater Roadrunner	*Geococcyx californianus*	MBTA	LLNL 2003
	Bell's Sage Sparrow	*Amphispiza belli*	CASCS, MBTA	LLNL 2003
	Black-throated Sparrow	*Amphispiza bilineata*	MBTA	LLNL 2003
	Rufous Crowned Sparrow	*Aimophila ruficeps*	MBTA	LLNL 2003
	Grasshopper Sparrow	*Ammodramus savannarum*	MBTA	LLNL 2003
	Lark Sparrow	*Chondestes grammacus*	MBTA	LLNL 2003
	California Towhee	*Carpodacus mexicanus*	MBTA	LLNL 2003
	Oregon Junco	*Junco hyemalis*	MBTA	LLNL 2003
	Lincoln's Sparrow	*Melospiza lincolnii*	MBTA	LLNL 2003
	Song Sparrow	*Melospiza melodia*	MBTA	LLNL 2003
	Vesper Sparrow	*Pooecetes gramineus*	MBTA	U.S. DOE and UC 1992
	Fox Sparrow	*Passerella iliaca*	MBTA	LLNL 2003
	Savannah Sparrow	*Passerculus sandwichensis*	MBTA	LLNL 2003
	Golden-crowned Sparrow	*Zonotrichia atricapilla*	MBTA	LLNL 2003
	White-crowned Sparrow	*Zonotrichia leucophrys*	MBTA	LLNL 2003
	American Kestrel	*Falco sparverius*	MBTA	LLNL 2003
	Prairie Falcon	*Falca mexicanus*	CASCS, MBTA	LLNL 2003
	House Finch	*Carpodacus mexicanus*	MBTA	LLNL 2003

Table C-1 (cont.). Site 300 wildlife species list. Includes species for which there are verified observations; it is not intended to be a complete list of Site 300 species.

Taxa	Common Name	Scientific Name	Regulatory Status[(a)]	Source
Birds (cont.)	Lesser Goldfinch	*Carduelis psaltia*	MBTA	LLNL 2003
	Cliff Swallow	*Petrochelidon pyrrhonota*	MBTA	LLNL 2003
	Northern Rough Winged Swallow	*Stelgidopteryx serripennis*	MBTA	LLNL 2003
	Tree Swallow	*Tachycineta bicolor*	MBTA	LLNL 2003
	Red-winged Blackbird	*Agelaius phoeniceus*	MBTA	LLNL 2003
	Tricolored Blackbird	*Agelaius tricolor*	CASCS, MBTA	LLNL 2003
	Brewer's Blackbird	*Euphagus cyanocephalus*	MBTA	LLNL 2003
	Bullock's Oriole	*Icterus bullockii*	MBTA	LLNL 2003
	Brown-headed Cowbird	*Molothrus ater*	MBTA	LLNL 2003
	Western Meadowlark	*Sturnella magna*	MBTA	LLNL 2003
	Loggerhead Shrike	*Lanius ludovicianus*	CASCS, MBTA	LLNL 2003
	Northern Mockingbird	*Mimus polyglottos*	MBTA	LLNL 2003
	California Thrasher	*Toxostoma redivivum*	MBTA	LLNL 2003
	California Quail	*Callipepla californica*		LLNL 2003
	Oak Titmouse	*Baeolphus inornatus*	FSC, MBTA	LLNL 2003
	Yellow-rumped Warbler	*Dendroica coronata*	MBTA	LLNL 2003
	Black-throated Gray Warbler	*Dendroica nigrescens*	MBTA	LLNL 2003
	Yellow Warbler	*Dendroica petechia*	CASCS, MBTA	LLNL 2003
	Common Yellowthroat	*Geothlypis trichas*	CASCS, MBTA	LLNL 2003
	MacGillivary's Warbler	*Oporornis tolmiei*	MBTA	LLNL 2003
	Orange-crowned Warbler	*Vermivora bachmanii*	MBTA	LLNL 2003
	Wilson's Warbler	*Wilsonia pusila*	MBTA	LLNL 2003
	Double-crested Cormorant	*Phalacrocorax auritus*	CASCS, MBTA	LLNL 2003
	Wild Turkey	*Meleagris gallopavo*		LLNL 2003
	Northern Flicker	*Colaptes auratus*	MBTA	LLNL 2003
	Nuttal's Woodpecker	*Picoides nuttallii*	MBTA	LLNL 2003
	Acorn Woodpecker	*Melanerpes formicivorus*	MBTA	U.S. DOE and UC 1992
	Pied-billed Grebe	*Podilymbus podiceps*	MBTA	LLNL 2003
	Phainopepela	*Phainopepla nitens*	MBTA	LLNL 2003
	Ruby-crowned Kinglet	*Regulus calendula*	MBTA	LLNL 2003
	Common Snipe	*Gallinago gallinago*	MBTA	LLNL 2003
	Greater Yellowlegs	*Tringa melanoleuca*	MBTA	LLNL 2003
	Burrowing Owl	*Athene cunicularia*	CASCS, MBTA	LLNL 2003
	Short-eared Owl	*Asio flammeus*	CASCS, MBTA	LLNL 2003
	Great horned Owl	*Bubo virginianus*	MBTA	LLNL 2003
	Western Screech Owl	*Otus kennicottii*	MBTA	LLNL 2003

Table C-1 (cont.). Site 300 wildlife species list. Includes species for which there are verified observations; it is not intended to be a complete list of Site 300 species.

Taxa	Common Name	Scientific Name	Regulatory Status[(a)]	Source
Birds (cont.)	European Starling	*Sturnus vulgaris*		LLNL 2003
	Western Tanager	*Piranga ludoviciana*	MBTA	LLNL 2003
	Anna's Hummingbird	*Calypte anna*	MBTA	LLNL 2003
	Costa's Hummingbird	*Calypte costae*	MBTA	LLNL 2003
	Rufous Hummingbird	*Selasphorus rufus*	MBTA	LLNL 2003
	Allen's Hummingbird	*Selasphorus sasin*	MBTA	U.S. DOE and UC 1992
	Rock Wren	*Salpinctes obsoletus*	MBTA	LLNL 2003
	Bewick's Wren	*Thyothorus ludovicianus*	MBTA	LLNL 2003
	House Wren	*Troglodytes aedon*	MBTA	LLNL 2003
	Hermit Thrush	*Catharus guttatus*	MBTA	LLNL 2003
	Swainson's Thrush	*Catharus ustulatus*	MBTA	LLNL 2003
	Varied Thrush	*Ixoreus naevius*	MBTA	LLNL 2003
	Mountain Bluebird	*Sialia currucoides*	MBTA	LLNL 2003
	Western Buebird	*Sialia mexicana*	MBTA	LLNL 2003
	American Robin	*Turdus migratorius*	MBTA	LLNL 2003
	Pacific-slope Flycatcher	*Empidonax difficillis*	MBTA	LLNL 2003
	Willow Flycatcher	*Empidonax traillii*	SE, MBTA	van Hattem 2005
	Ash-throated Flycatcher	*Myiarchus cinerascens*	MBTA	LLNL 2003
	Western Wood-pewee	*Contopus sordidulus*	MBTA	U.S. DOE and UC 1992
	Black Phoebe	*Sayornis nigricans*	MBTA	LLNL 2003
	Say's Phoebe	*Sayornis saya*	MBTA	LLNL 2003
	Western Kingbird	*Tyrannus verticalis*	MBTA	LLNL 2003
	Cassin's Kingbird	*Tyrannus vociferans*	MBTA	LLNL 2003
	Barn Owl	*Tyto alba*	MBTA	LLNL 2003
Invertebrates	Valley elderberry longhorn beetle	*Desmocerus californicus dimorphus*	FT	Arnold 2002
	California fairy shrimp	*Linderiella occidentalis*		Weber 2002
	California clam shrimp	*Cyzicus californicus*		Weber 2002

(a) CAFPS = California Department of Fish and Game Fully Protected Species (CA Dept. of Fish and Game 2006)
CASCS = California Special Concern species (CA Dept. of Fish and Game 2006)
FE = Endangered under the Federal Endangered Species Act
FT = Threatened under the Federal Endangered Species Act
PT = Proposed as threatened under the Federal Endangered Species Act
MBTA = Migratory Bird Treaty Act
SE = Endangered under the State Endangered Species Act
ST = Threatened under the State Endangered Species Act
FSC = Federal Species of Concern for Alameda and San Joaquin Counties. May be endangered or threatened. Not enough biological information has been gathered to support listing at this time (U.S. Fish and Wildlife Service 1-1-03-SP-0162).

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APPENDIX D
Extra Resources

The documents listed below are accessible as PDFs on CD or at https://saer.llnl.gov, the website for the LLNL annual environmental report. In the electronic version of this appendix, the resources are linked to the PDFs.

Livermore Site Storm Water Monitoring for Waste Discharge Requirements 95-174, 2006–2007

Campbell, C.G. and K. Brunckhorst. (2007). *Lawrence Livermore National Laboratory Livermore Site Annual Storm Water Monitoring Report for Waste Discharge Requirements 95-174, Annual Report 2006-2007*. Livermore, California: Lawrence Livermore National Laboratory, UCRL-AR-126783-07.

LLNL Ground Water Project Annual Report, 2007

Karachewski, J., P. McKereghan, L. Berg, E. Folsom, J. Coty, and M. Dresen, eds (2008). *LLNL Ground Water Project 2007 Annual Report*. Livermore, California: Lawrence Livermore National Laboratory, UCRL-AR-126020-07.

LLNL NESHAPs Annual Report, 2007

Bertoldo, N.A., J.M. Larson, and K.R. Wilson. (2008). *LLNL NESHAPs 2007 Annual Report.* Livermore, California: Lawrence Livermore National Laboratory, UCRL-TR-113867-08.

Site 300 Building 829 Compliance Monitoring Annual Report, 2007

Revelli, M.A. (2008). *Lawrence Livermore National Laboratory Experimental Test Site 300—Compliance Monitoring Program for the Closed Building 829 Facility—Annual Report 2007*. Livermore, California: Lawrence Livermore National Laboratory, UCRL-AR-143121-07.

Site 300 Compliance Monitoring Annual Report, 2007

Dibley, V., S. Gregory, M. Taffet, V. Madrid, J. Valett, M. Denton, T. Carlsen, Z. Demir, D. Mason, P. McKereghan, R. Goodrich, and S. Chamberlain. (2008). *2007 Annual Monitoring Compliance Report for Lawrence Livermore National Laboratory Site 300*. Livermore, California: Lawrence Livermore National Laboratory, UCRL-AR-206319-07.

Site 300 Compliance Monitoring for Waste Discharge Requirements 96-248 Annual Report, 2007

Ridley, M. (2008). *LLNL Experimental Test Site 300 Compliance Monitoring Report for Waste Discharge Requirements 96-248, Annual/Fourth Quarter Report 2007*. Livermore, California: Lawrence Livermore National Laboratory, UCRL-AR-125915-07-4.

Site 300 Storm Water Monitoring for Waste Discharge Requirements 97-03-DWQ Annual Report, 2007

Brown, R. (2007). *Lawrence Livermore National Laboratory Site 300 Annual Storm Water Monitoring Report for Waste Discharge Requirements 97-03-DWQ*. Livermore, California: Lawrence Livermore National Laboratory, UCRL-AR-144362-07.

Site 300 Pit 6 Compliance Monitoring Annual Report, 2007

Campbell, C. and M.J. Taffet. (2008). *LLNL Experimental Test Site 300 Compliance Monitoring Program for the CERCLA-Closed Pit 6 Landfill, Annual Report 2007*. Livermore, California: Lawrence Livermore National Laboratory, UCRL-AR-132057-07-4.

Site 300 Pits 1 and 7 Compliance Monitoring Annual Report, 2007

Campbell, C. and D.H. MacQueen. (2008). *LLNL Experimental Test Site 300 Compliance Monitoring Program for RCRA-Closed Landfill Pits 1 and 7, Annual Report for 2007*. Livermore, California: Lawrence Livermore National Laboratory, UCRL-10191-07-4.

Supplementary Topics on Radiological Dose

Sanchez, L., P.E. Althouse, N.A. Bertoldo, R.G. Blake, S.L. Brigdon, R.A, Brown, C.G. Campbell, T. Carlson, E. Christofferson, L.M. Clark, G.M. Gallegos, A.R. Grayson, R.J. Harrach, W.G. Hoppes, H.E. Jones, J. Larson, D. Laycak, D.H. MacQueen, S. Mathews, M. Nelson, L. Paterson, S.R. Peterson, M.A. Revelli, M.J. Taffet, P.J. Tate, R. Ward, R.A. Williams, and K. Wilson. (2003). *Environmental Report 2002*. Livermore, California: Lawrence Livermore National Laboratory, UCRL-50027-02, Appendix D.

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APPENDIX E
Errata

Protocol for Errata in LLNL Environmental Reports

The primary form of publication for the LLNL Environmental Report is electronic: the report is posted on the Internet. A limited number of copies are also printed and distributed, including to local libraries. If errors are found after publication, the Internet version is corrected. Because the printed versions cannot be corrected, errata for these versions are published in a subsequent report. In this way, the equivalency of all published versions of the report is maintained.

In 1998, LLNL established the following protocol for post-publication revisions to the environmental report: (1) the environmental report website must clearly convey what corrections, if any, have been made and provide a link to a list of the errata, (2) the Internet version must be the most current version, incorporating all corrections, and (3) the electronic and printed versions must be the same in that the printed version plus errata, if any, must provide the same information as the Internet version.

LLNL environmental reports from 1994 through 2007 can be accessed at https://saer.llnl.gov/.

Record of Changes to Environmental Report 2005

The following changes have been made to the Internet version of *Environmental Report 2005*.

- Page 7-11, Table 7-5: Detection limits for plutonium-239 and uranium-238 were changed from 1.9×10^{-4} and 1.1×10^{-4}, respectively, to 1.9×10^{-8} and 1.1×10^{-9}, respectively.
- Page 9-10, Table 9-5: In footnote b, the absolute value in the equation was changed from $|x_1 \pm x_2|$ to $|x_1 - x_2|$.

Record of Changes to Environmental Report 2006

The following changes have been made to the Internet version of *Environmental Report 2006*.

- Page 5-44, Section 5.5.1, last line of the first paragraph: "Section B.6" was changed to "Section B.7".
- Page 5-46, Section 5.5.2, last line of the second paragraph: "Section B.6" was changed to "Section B.7".
- Page 5-48, Section 5.5.3, last line of the fourth paragraph: "Section B.6" was changed to "Section B.7".
- Page 6-13, Table 6-6: Title changed from "Quarterly concentrations of tritium…" to "Quarterly, median, and mean concentrations of tritium…".

- Page 6-14, Figure 6-5: Labels for Near and Far in legend were corrected to Triangle = Near and Square = Far.
- Page 7-10, Table 7-5: Detection limits for plutonium-239 and uranium-238 were changed from 1.9×10^{-4} and 1.1×10^{-4}, respectively, to 1.9×10^{-8} and 1.1×10^{-9}, respectively.
- Appendix B, Section B.8: Titles on Tables B.8.4, B.8.5, and B.8.6 changed from "Background concentration values for metals in soils at the Livermore site, 2006" to the following:
  - Table B.8.4: Changed to "Radionuclides in soils and sediments in the Livermore Valley, 2006".
  - Table B.8.5: Changed to "Fallout and background radionuclides in soil at Site 300, 2006".
  - Table B.8.6: Changed "Background concentration values for metals in soils at Site 300, 2006".

READER SURVEY

Lawrence Livermore National Laboratory Environmental Report 2007

The purposes of this annual report are to record LLNL's compliance with environmental standards and requirements, describe LLNL's environmental protection and remediation programs, and present the results of environmental monitoring at the two LLNL sites—the Livermore site and Site 300.

We strive to provide information that is understandable and clear and that communicates effectively the Laboratory's efforts to protect human health and the environment. We also try to make the electronic version of the report and the website where it is posted (https://saer.llnl.gov/) as user friendly as possible. Your feedback on this survey will help us gauge how successful we have been.

Your input will be carefully considered.

I ❑ have ❑ do not have technical knowledge in the environmental sciences.

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The background information was ❑ sufficient ❑ insufficient ❑ inconsistent ❑ just right.

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The illustrations and tables were ❑ helpful ❑ difficult to understand.

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